WAVE ATTENUATION BY FLOATING BREAKWATER

ADELINE ERNITY KEHING

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JANUARY 2008

Wave Attenuation by Floating Breakwater

by

Adeline Ervity Kehing

5686

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

JANUARY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Wave Attenuation by Floating Breakwater

by

Adeline Ervity Kehing

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(Assoc. Prof. Saied Saiedi)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ADELINE ERVITY KEHING

ACKNOWLEDGEMENT

My highest gratitude to our Lord God for all the blessings He has showered onto us.

Thank you to my supervisor, Assoc. Prof. Saied Saiedi, lecturers and laboratory technicians of Department of Civil Engineering for guiding me throughout the whole process of completing this Final Year Project.

My deepest appreciation to my family - my parents, Mr. and Mrs. Lucas Saging Kehing, and my siblings; individuals especially my colleague, Ng Boon Hock; friends, Mohd Hazman, Razwan Rashid and Raja Deen Hawari for assisting me in laboratory experiments and giving me the support I needed.

Sincerely,
Adeline Ervity Kehing

ABSTRACT

In recent years, series of studies has been conducted to evaluate the wave attenuation ability of a floating breakwater model namely the Wave Suppress System (WSS). A prototype model was designed to provide a shape which could effectively attenuate waves with the aim of determining the ability of the structure in various conditions. An experimental project on the wave attenuation ability of a floating breakwater was carried out as a final year project to further improve the performance of the WSS. The aim of this study is to evaluating the performance of three floating breakwater models in terms of transmission which was done experimentally and analysed in detail and in terms of reflection and energy loss which were made through observations during the sessions of experiments. Besides that, discussions were made to determine the factors that affect the attenuation ability of the floating breakwater models. Twelve sets of experiments were conducted and several literatures on previous tests done on floating breakwater have been reviewed throughout the study. With reference to the original design of the WSS floating breakwater, three floating breakwater models was fabricated for the study – M1, M2, and M3 which were all made of wood assembled into a hollow box with a basic shape of 30 cm long, 20 cm wide and 10 cm tall. All models are proven theoretically and experimentally stable having a draft of 6 cm for M1, 6.9 cm for M2, 4.9 cm for M3. Laboratory experiments were conducted to evaluate the performance of all three floating breakwater models. The results were presented and analysed clearly in this report. It was found that the performance of all three floating breakwater models were more effective when fixed by piling systems. The C_T values for M1, M2 and M3 were smaller when anchored by pile system compared to cable. The wave attenuation ability of all floating breakwater models were more effective in water depth of 20 cm for pile system while for cable system, the models were more effective in water depths of 30 cm. In conclusion, M2 performs best for pile category while M3 attenuates more wave energy for cable system category.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	Amplitude
a_x, a_y, a_z	Respective components of acceleration in the x-, y- and z-directions
B	Width of floating breakwater models
C	Celerity
C_G	Speed of wave group
C_L	Energy loss coefficient
C_R	Reflection coefficient
C_T	Transmission coefficient
D	Draft of floating breakwater models
d	Water depth
d_b	Depth of breaking
E	Wave energy
E_K	Kinetic energy
E_P	Potential energy
f	Frequency
g	Acceleration due to gravity
H	Wave height
H_b	Breaker height
H_i	Incident wave height
H_o	Deep water wave height
H_r	Reflected wave height
H_t	Transmitted wave height
k	Wave number
K_s	Shoaling factor
L	Wavelength
L_b	Breaker wavelength
n	Group velocity factor
p	Pressure
P	Wave power
s	Elevation from ocean floor or cable length
T	Wave period
t	Time

T_b	Breaker period
u, v, w	Respective components of velocity in the x-, y-, z-directions
x, y, z	Ordinates in horizontal and vertical directions
α	Angle between wave crest and seabed contour
β	Angle between slope normal and direction of wave propagation or wave orthogonal
ϕ	Velocity potential
η	Water surface elevation above a fixed datum
ρ	Density of water
θ	$k(x-Ct)$
ξ, ζ	Particle displacements in x- and z- directions
ω	Wave angular frequency

CHAPTER 1
INTRODUCTION

Most human activities took place along the coastline, even from the early existence of human community. Coastal areas provide important economic values and a mode of transportation, as well as for residential and recreational purposes. The value of the coastal areas depends on its physical characteristics, appealing landscape, cultural heritage, natural resources and rich marine and terrestrial biodiversity (Reeve, 2004).

The current world's coastlines formed as a result of the last ice age, which ended about 10,000 years ago. Before, there were more areas of large ice covering earth than they are today. As the ice melted, coastline begin to form and become beaches which later face one of the most important issue these days – coastal erosion.

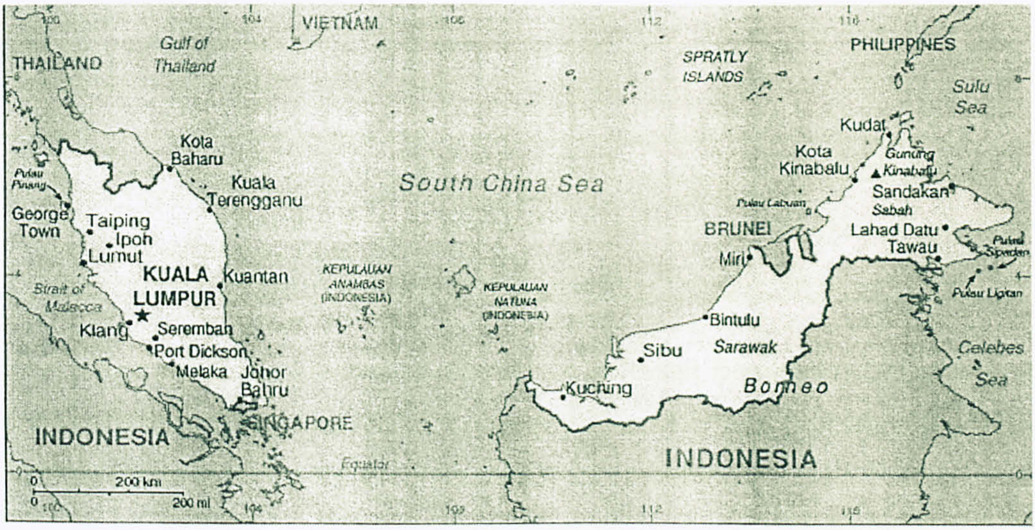


Figure 1: Map of Malaysia

Coastline is defined as the boundary line between the coast and the shore while shoreline is the intersection of a specified plane of water between the beach and shore. According to the World Factbook, the world's total coastline is 365,000 kilometres with Canada owning more than 50 percent of the world's coastline. Malaysia (see Figure 1) owns only 1.3 percent of this number.

The National Coastal Erosion Study (NCES) was carried out by the Malaysian Government which was conducted from November 1984 to January 1986. It was found that at the end of the study, Malaysia's coastline was 4,809 kilometres – 29 percent (1,400 kilometres) faces erosion problems (see Table 1).

Table 1: Coastal erosion in Malaysia according to category (from National Coastal Erosion Study)

State	Length of Coastline Unit: km	Category I* Unit: km	Category II* Unit: km	Category III* Unit: km	Total Erosion km	Total Erosion %
Perlis	20	4.4	3.5	6.4	14.3	71.5
Kedah	148	22.6	2.6	12.4	37.6	25.4
Penang	152	36.7	19.1	1.1	56.9	37.4
Perak	230	25.8	21.3	93.1	140.2	61.0
Selangor	213	55.3	32.9	66.1	154.3	72.4
N.Sembilan	58	2.0	9.6	12.9	24.5	42.2
Melaka	73	9.2	22.1	3.0	34.3	47.0
Johor	492	18.8	53.2	165.7	237.7	48.3
Pahang	271	9.6	2.8	107.8	120.2	44.4
Terengganu	244	20.0	12.8	122.4	155.2	63.6
Kelantan	71	5.0	10.9	37.6	53.5	75.4
Labuan	59	1.5	4.0	25.1	30.6	51.9
Sarawak	1035	9.0	22.8	13.7	45.5	4.4
Sabah	1743	12.8	3.5	279.2	295.5	17.0
TOTAL	**4809**	**232.7**	**221.1**	**946.5**	**1400.3**	**29.1**

** Category I as critical erosion area where facilities are in immediate danger.*
Category II as significant erosion area where facilities will be endangered within a period of 5-10 years if no measures are taken.
Category III as acceptable erosion area which is generally undeveloped and has no facilities.

As a result, the government then set up a Coastal Engineering Department in the Department of Irrigation and Drainage (DID) in 1987 to protect coastline facing critical erosion as well as the properties along the coastline.

Today, according to the World Factbook (updated March 2008), Malaysia's coastline is 4,675 kilometres with Peninsular Malaysia having 2,068 kilometres and East Malaysia having 2,607 kilometres.

Coastal erosion is the local loss of sub-aerial coastal landmass due to natural processes such as waves, winds and tides, or in some cases, due to human interferences. As this problem becomes more and more of an issue these days, Coastal Engineers around the world struggle to fine a way to reduce the amount of coastline eroded, not only to protect the shore but also the properties within the coastal area.

Action has been taken to prevent coastal erosion. The general term used to cover all aspect of defence against coastal hazards is coastal defence (Reeve, 2004). The two types which used to distinguish the different types of hazards are 'sea defence' – methods designed to prevent flooding of coastal regions under extreme waves and water levels; and 'coastal protection' – methods designed to protect an existing shoreline from further erosion.

There are two approaches to coastal defence – soft structure and hard structures. Soft structures simply work with natural processes by mimicking the natural defence mechanisms such as beach nourishment, floating breakwater, artificial sea grass and artificial reef. This approach minimizes the environment impact, creates environmental opportunities and known to be environmentally friendly. Hard structures are structures constructed, or in other words, fixed permanently on the coastline to resist the energy of waves and tides e.g. offshore breakwater, groynes, seawalls and revetments, this approach may cause severe changes to the landscape and the environment.

Breakwaters are used widely especially in Malaysia to protect coastlines. The main function of a breakwater is to reduce or eliminate the intensity of wave action in inshore waters, hence reducing coastal erosion. The breakwater creates a sheltered region at the leeward side, not only to prevent damages to the coastline but also to protect harbours and other natural or man-made structures. There are two types of breakwaters – fixed breakwater (hard structures) and floating breakwater (soft structures). This study focuses on floating breakwater as wave attenuator.

Fixed breakwater is a very well-known method of coastal protection. The simple design and ease of construction made it the most chosen method used especially in Malaysia. It has been widely used all over the world. One of Dubai's mega projects, 'The World', owns the longest breakwater ever constructed measuring 27 km (see Figure 2). Since fixed breakwater acts as a total barrier, intensive studies have to be done to make sure there are proper circulations of water surrounding the 300 man-made islands which are protected by the breakwater. Fixed breakwater is known to have much longer design life, sometimes reaching 100 years. The Cobb at Lyme Regis, constructed in the 13th century is the oldest working breakwater (see Figure 3).

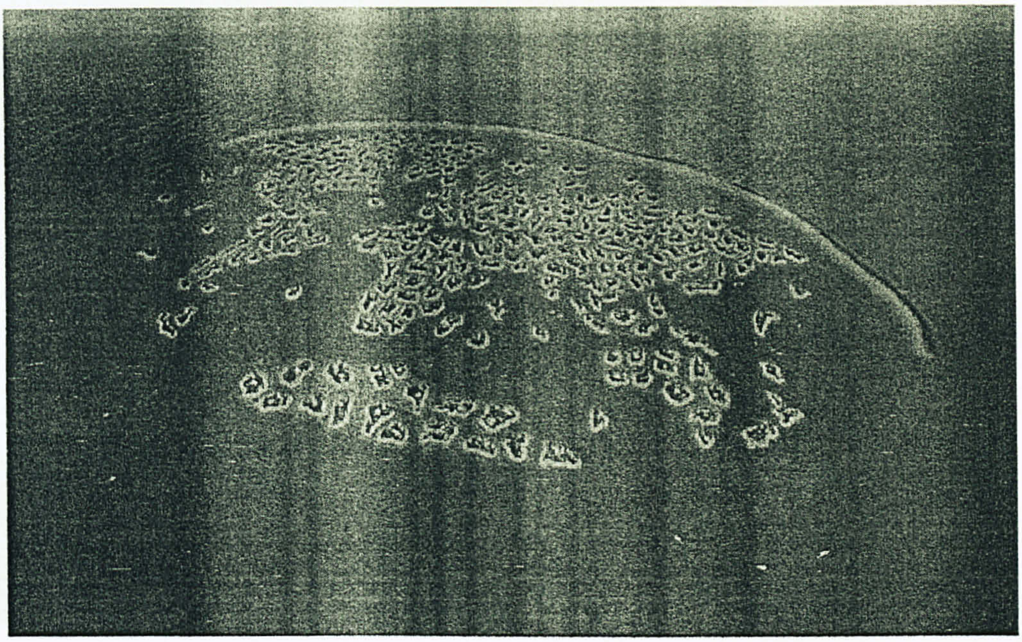


Figure 2: The longest rubble mound breakwater protecting The World in Dubai against incident waves (http://www.arabianbusiness.com/512591-island-paradise?ln=en)

Foustert (2006) categorized breakwaters into 3 types namely, conventional (mound) breakwater, monolithic breakwater, and composite breakwater. Conventional or also known as rubble mound breakwater is basically a large heap of loose elements such as gravel and quarry stones or concrete armours. Monolithic breakwaters have a cross-section designed in a way that the structure acts as a solid vertical block. Composite breakwater is the combination of both conventional and monolithic type preferable in large water depths.

Rubble-mound breakwater is one of the most used which is typically construct with a core of quarry-run stone, sand or slag and protected by layers of concrete armour units. Fixed breakwater generally is an excellent wave attenuator but somehow it contributes significant damage to the environment. Studies on the design of the fixed breakwater have to be done carefully before it is constructed because once constructed, very few are ever removed and they may cause permanent damage to the environment. This may cause a very expensive penalty for a mistake.

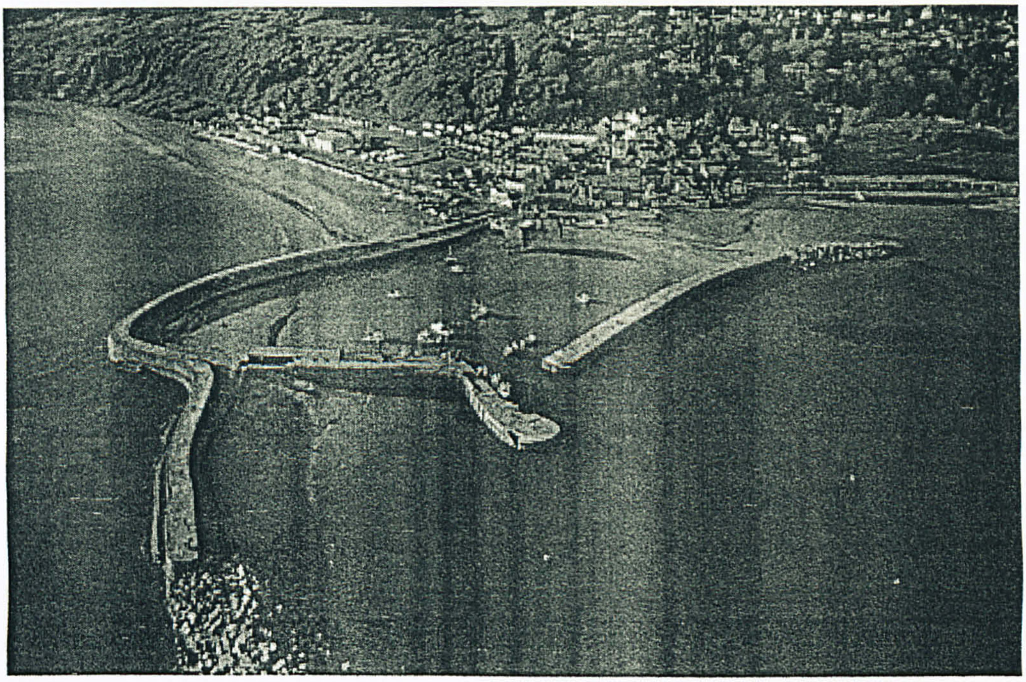


Figure 3: Oldest fixed breakwater at The Cobb, Lyme Regis

Fixed breakwaters are bottom founded, so it may cost a great amount of money for reconstruction and maintenance to maintain the required height of the breakwater as it settles. Fixed breakwater also acts as a total barrier to close off a significant potion of a waterway or entrance channel which thereby causing a faster river or tidal flow in the vicinity as well as potentially trapping debris on the up-drift side. This will then creates a sedimentation problems and water quality problems due to poor circulation. The construction of fixed breakwater for Dubai's Palm Jebel Ali which was 200 m wide and 17 km long was done and studied carefully to make sure that the water surrounding the artificial peninsulas circulate properly. Besides that, detached fixed breakwater can also cause the formation of tombolo (see Figure 4) which may be a draw back for certain areas as this can seriously interrupt longshore sediment transport and cause downdrift erosion. The formation of tombolo could be a method in cases where the width of the beach is needed to be increased, naturally.

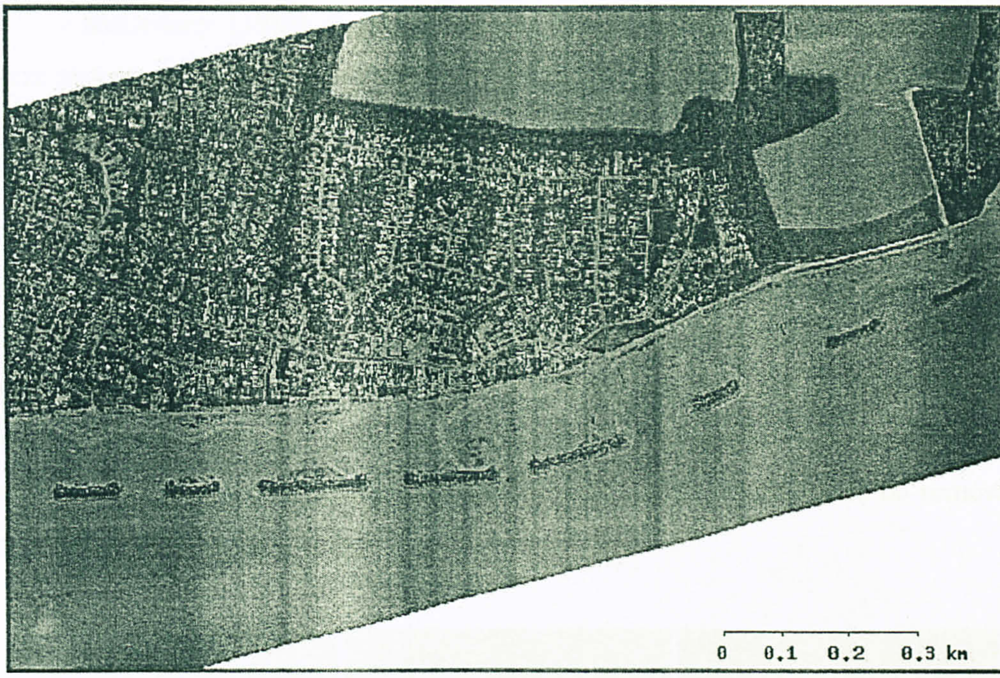


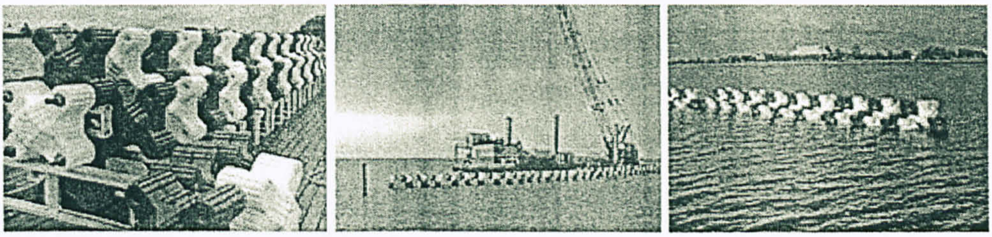
Figure 4: Formation of tombolo (Elmer, UK)

Even though it is considered costly, at site with high level of less than about 2 m deep, fixed breakwater is considered to be most economical (McCartney, 1985). But as water level increase, the cost of construction would be very expensive. McCartney concluded that it is uneconomical and impractical to build and maintain a fixed breakwater in water depth more than 6 m as it would need a high wall to be built while most of the wave energy will be distributed at the upper portion of water depth. The overall construction cost of a fixed breakwater increases exponentially with depth (Sorensen, 1978).

In 1811, the first wooden floating breakwater of the modern era was constructed at Plymouth Port, England which showed an encouraging performance in attenuating waves. Bombardon breakwater was built during the invasion of Normandy in World War II for protection of amphibious naval operations. The number of floating breakwater used today increases significantly as studies have been able to prove the effectiveness of a floating breakwater in certain area. Their low cost and versatility makes it popular especially at high value beaches. Cypremort

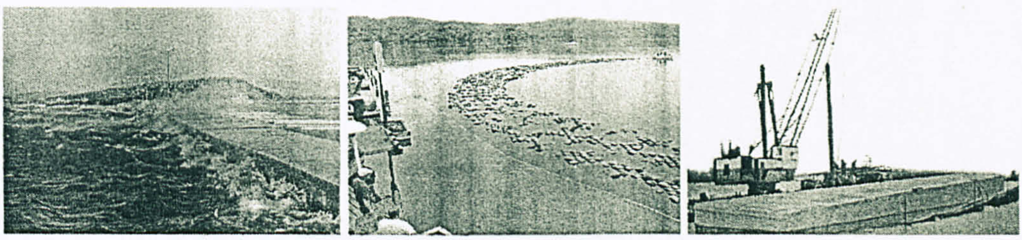
Point State Park Beach in LA installed 500 m long WhisprWave® polygon modules in 2003 (see Figure 5) which consists of red and white units connected like building cubes.

McCartney (1985) classified floating breakwaters in 4 types according to their shapes and similarities – box type, pontoon type, mat type and tethered type (see Figure 6). Floating breakwater is still considered a new technology in the coastal world. Its performance is still in doubt as there are quite a number of limitations in terms of its efficiency in attenuating waves. Nevertheless, floating breakwater has been used as it has been known for its versatility and low cost of construction. Environmentalist around the world accepts floating breakwaters as a friendly approach to saving the coastline as it has very little impact to the environment. The needlessness of a foundation for the structure makes it leave no such damage to the seabed. The small size of floating breakwater also makes it possible to be removed and relocated into a new layout.



(a) (b) (c)

Figure 5: Cypremort Point State Park, LA floating breakwater installed October 2003 (a) Assembly of modules, (b) Floating breakwater installed, (c) Installation complete



(a) (b) (c)

Figure 6: Types of floating breakwater. (a) Pontoon type floating breakwater. Designed and manufactured my SF Marina System Ab. (b) Mat type breakwater made from used tire in Lake Champlain, North America. (c) Box type floating breakwater Cowichan Bay, BC

Both fixed and floating breakwater offers the best of its ability in attenuating waves approaching the shore. There are advantages and disadvantages for both approaches (see Table 2). In general, fixed breakwater has permanent impact to the environment while the floating breakwater causes almost no permanent damage to the shore.

Table 2: Summary on advantages and disadvantages for fixed and floating breakwater

Fixed Breakwater	**Floating Breakwater**
Advantages	
Excellent storm protection. Easy to construct. Does not need links or connections, hence higher strength. Longer design life. Does not response to the movement of waves. Structure can be used for other coast activities. Permanent.	Low cost of construction in deep water. Less interference to the environment. Flexible and easy to be removed, relocated and rearranged into a new layout. Independence from poor foundation. Adaptable to water level change. Aesthetics. Shorter construction period.
Disadvantages	
May harm the environment. Causes permanent damage to the landscape and environment. Total barrier to sediment transport and may cause severe erosion in the downdrift side as well as forming a tombolo. Very costly and impractical for deep water depths. May be overtopped by higher waves. Pieces of broken armour or quarry stones may dirty the beaches. Scour at the toe of structure may cause severe damage. Rely on bottom foundation.	Not suitable for very exposed location. Limitation in terms of strength of cables or mooring lines. May be a danger to ships, coast or offshore structures when broken. Shorter design life. Weak link or connection between each modules. Moves in response to wave action, thus more prone to structural fatigue. Vertical and horizontal movement greatly reduces the attenuation ability. May take a large amount of water surface (e.g. floating tyre breakwater).

1.1 BACKGROUND OF STUDY

Increasing amount of reports is presented on the impact of waves towards the coastline. Hence, protection measures for coastlines are taken seriously in order to protect the coastline, including the value and the properties within the area. As known, breakwaters are structures used to reduce more damages caused by the impact of waves. This study takes floating breakwaters' performance in transmitting wave energy into account.

In the previous years, Universiti Teknologi PETRONAS has come up with an innovative design of floating breakwater named 'Wave Suppress System' (WSS). Series of experiments and tests were done to study the performance of the prototype model of WSS, and it has been proven by Mr. Teh *et. al.* (2002) that the WSS is able to attenuate waves effectively. The earlier experiments were a comparison between WSS, inverted WSS and a box model as control. The following tests were comparing the WSS with modified versions of WSS which were GEN-2 and GEN-2 with keel plate. In all experiments, the models were fixed in place with a steel rod penetrating the centre of the models and all models were made of light-weight concrete.

Another study was conducted by previous undergraduates in fulfilment to the requirements of bachelor degree in Universiti Teknologi PETRONAS. The study experimented on the performance of WSS – GEN-2 with keels, having porosities of 0, 15 and 30 percent.

From the design of WSS, another series of experiments were done for this study in continuation to the pervious studies and also to improve the performance of a floating breakwater in general. Improvements were made to the models, such as the materials used and the anchoring system while still keeping the basic design of the models. Three new duplicate models (see Figure 7) of WSS were fabricated, namely M1, M2 and M3. The general purpose of this study is to uncover more possible improvement towards the WSS model.

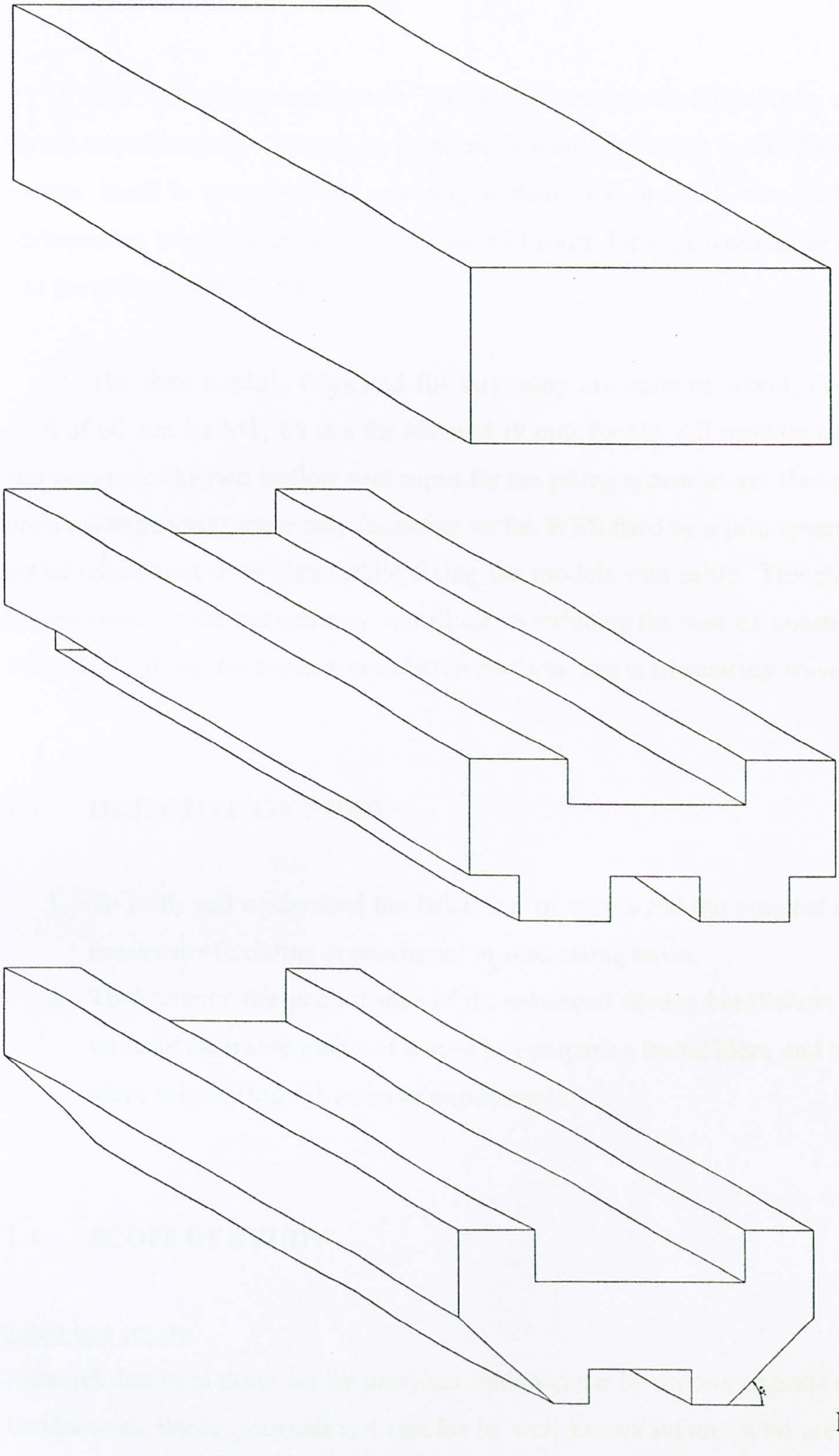


Figure 7: Sketch of the floating breakwater models

1.2 PROBLEM STATEMENT

The 'Wave Suppress System' (WSS) has been proven effective in attenuating waves, experimentally. Though so, there are limited alternatives to the design and the system itself in terms of the mooring system, the material, etc. Although its performance is proven effective, there are still room for improvement in the design and the system of the WSS.

The three models fabricated for this study are made of wood, floating with draft of 60 mm for M1, 69 mm for M2 and 49 mm for M3. All models were hollow and penetrated by two hollow steel pipes for the piling system to get through. As the previous experiment were only focussing on the WSS fixed by a pile system, another set of experiment were done while fixing the models with cable. The changes and improvement of the system may contribute to reducing the cost of constructing the WSS while giving the same or even better performance in attenuating waves.

1.3 OBJECTIVE OF STUDY

1. To study and understand the behaviour of waves and the concept of floating breakwater (existing or prototype) in attenuating waves.
2. To determine the performance of the enhanced floating breakwater models in terms of the transmission of waves by comparing the incident and transmitted wave heights through series of experiments.

1.4 SCOPE OF STUDY

Literature review

Research has been done on the previous studies done by various experts of floating breakwaters. Books, journals and articles by well known authors who are experts in this field were frequently and continuously referred to throughout this study. The compilation of the readings and research from this aspect were summarized and compared in the next chapter.

Learning and understanding the functions of the wave flume in UTP, Tronoh

Tests were conducted to learn and understand the procedure and on how to operate the wave flume in Universiti Teknologi PETRONAS, Tronoh. The relationship between the frequency set by the control box of the flume and the wave period generated by the wave maker were determined through plots of frequency, f versus wave period, T obtained from the average time of a cycle of 5 to 10 successive waves.

Determining suitable parameters for data analysis

Through the research done, several dimensionless parameters were obtained in order to compare the performance of the floating breakwater models. Parameters used include the draft and width of the floating breakwater models, water depth, wave period, wavelength, and incident and transmitted wave heights.

Understanding the design concept of floating breakwater and waves

Through intensive readings and core subjects taken during the period of this study, efforts were taken to understand the design concept of a floating breakwater, may it be a real existing model or prototype; and the behaviour of waves through Coastal and Offshore Engineering subject. The theories, characteristics, mechanisms and processes of waves were evaluated and understood throughout the study.

Proposing an enhance design and new series of experiment

An enhance design for the WSS were proposed for the study. Modifications were made for better attenuation performance of the models. The modifications made include the material used, the anchoring systems and the range of water depth and wave periods. Proposal made were based on the literature study made throughout the study.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 LITERATURE REVIEW

Although it has been seen that fixed breakwaters are well-known and universally used as excellent wave energy suppression, the fixed breakwater contributes a significant amount of drawbacks especially to the environment. In some cases, a floating breakwater provides more reasons and advantages compared to the use of a fixed breakwater. Poor bottom conditions and reserved coral reefs caused engineers and environmentalist to hesitate on constructing a fixed breakwater. The high cost of constructing a fixed breakwater in deep water and the steeply sloping shelf environment makes a floating breakwater a better solution.

When wave attacks the floating breakwater, the energy will be reflected, dissipated, induce breakwater motions and pass through beneath the structure. The induced body motions of the floating breakwater will be restrained by the mooring lines. In summary, a floating breakwater attenuates wave energy by reflecting the wave energy and dissipating it by induced turbulent motions. There are many types and shapes of floating breakwater modules designed up to this day to provide satisfactory level of wave attenuation. There are mainly four type of floating breakwater rationally classified to its geometric and functional similarities, namely, box, pontoon, mat and tethered type (McCartney, 1985).

The main factor in constructing a floating breakwater is to make the width (in direction of wave propagation) greater than one half the wavelengths but preferably as wide as the incident wavelength or else the breakwater will ride on top of the wave without attenuating the incident wave energy (Hedge, Kamath and Deepak, 2007). An optimum design should give a large degree of attenuation of wave heights and less force on the mooring lines. Several studies has been done on various design for the pass few years up to this day.

An experimental study on wave attenuation performance of a floating breakwater called Wave Suppress System (WSS) was done by Teh et al. (2006). WSS is designed to alleviate Malaysia's over-dependency on foreign technologies to protect the coastal regions in Malaysia. The paper describes the performance of WSS as an environmental-friendly wave attenuation structure. Laboratory experiments were conducted to determine the wave transmission characteristics under various wave conditions.

The WSS model is 30 cm long, 20 cm wide and 10 cm tall with inverted steps at both sides (see Figure 8). The WSS model was tested in a 12 m long by 0.3 m wide and 0.45 m deep flume in the Hydraulics Laboratory of *Universiti Teknologi PETRONAS.* The model was subjected to steady monochromatic non-breaking wave generated by a flap-type wave maker throughout the experiment. A wave absorber was installed at the opposite end to absorb the wave energy in order to reduce the reflected waves.

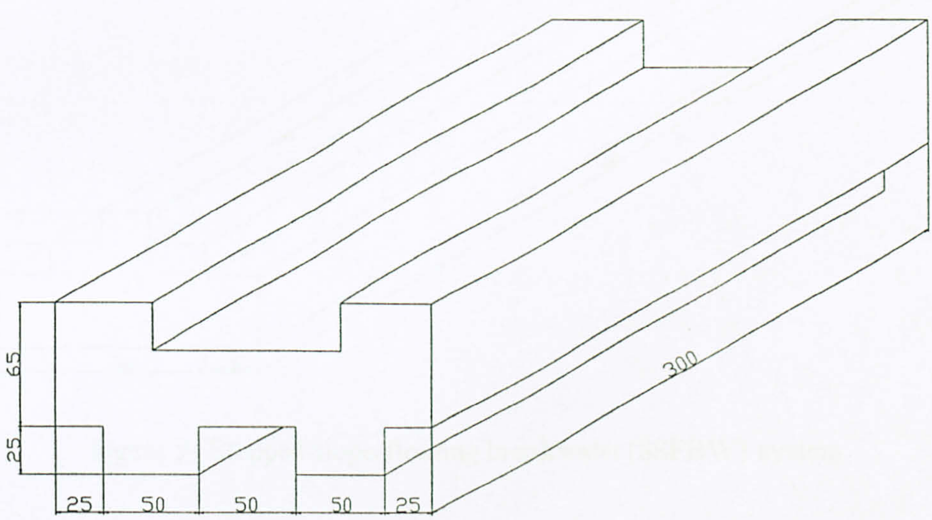


Figure 8: Wave Suppress System (WSS)

The model was fixed 8 m from the wave maker with a steel rod which acts as pile mooring system. The experiment tests were conducted for more than 10 wave periods (ranging from 0.5 sec to 3.5 sec) in water depths of 20 cm, 25 cm, and 30 cm.

The WSS model tested was compared with an inverted WSS model and a box-type model.

Coefficient of reflection C_R, transmission C_T, and loss of energy that is mainly due to breaking waves and friction on the structure surface, C_L were determined through the experiments. The results shows that C_R and C_L of WSS in water depth ranging from 20 cm to 30 cm were 0.2 – 0.5 and 0.5 – 0.9 respectively. This means that the WSS is an effective wave-energy dissipater but a poor wave reflector. The WSS attenuates incoming waves by the action of breaking and friction over body of floating structure rather than reflection. The results also showed that the geometrical factor of the floating structure and the wave conditions does affect the degree of wave attenuation. Overall conclusion says that the WSS is more effective in shallow waters.

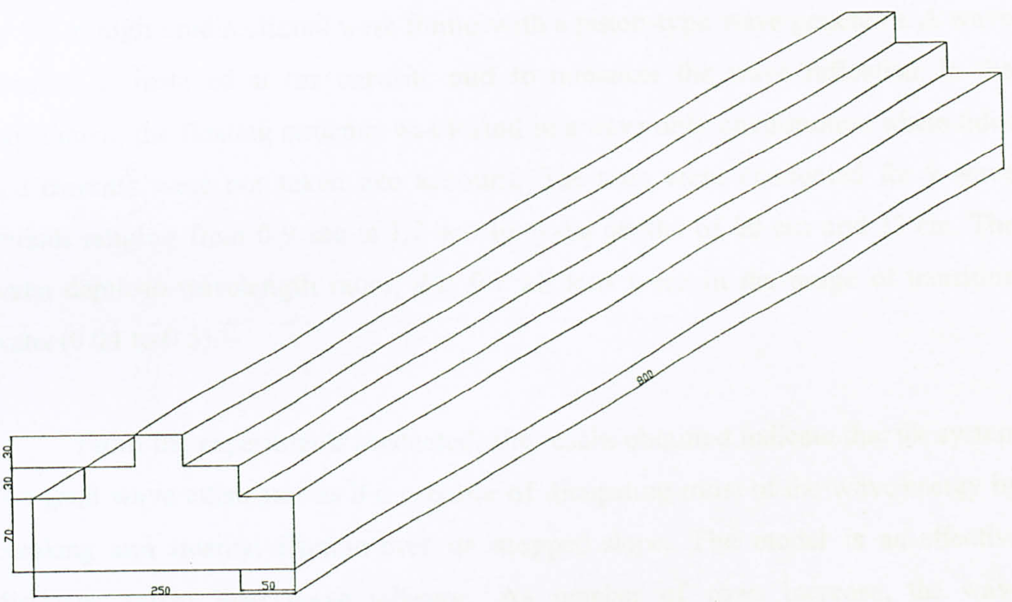


Figure 9: Stepped-slope floating breakwater (SSFBW) system

Ismail et al. (2002) investigate the wave attenuation characteristics of a stepped-slope floating breakwater system. The paper described the performance of a floating breakwater system having a stepped-slope on each side (see Figure 9). The objective of the experiment was to determine the wave transmission characteristics in various breakwater geometry and wave conditions. A series of unidirectional regular wave was generated on the floating structure. Transmitted wave heights behind the structure were investigated to obtain the coefficient of transmission, reflection and the amount of energy lost. The results showed that the degree of wave attenuation was dependent strongly on the geometrical factors and wave conditions.

The primary factors considered in the experiments which relate the wave attenuation with the floating breakwaters are the breakwater width *B*, breakwater draft *D*, wave steepness *H/L*, and water depth *d*. The transmitted wave height H_t were characterized by *B* and *D* while the incident wave height H_i were described by its height, period and wavelength, thus giving the transmission coefficient as;

$$C_T = H_t/H_i = \left(B/L, D/L, H_i/gT^2, d/gT^2\right)$$

The laboratory experiments were conducted in an 18 m long by 0.95 m wide by 0.9 m high unidirectional wave flume with a piston-type wave generator. A wave absorber is installed at the opposite end to minimize the wave reflection. In the experiment, the floating structure was tested in a wave only environment where tides and currents were not taken into account. The tests were conducted for 9 wave periods ranging from 0.9 sec to 1.7 sec in water depths of 20 cm and 33 cm. The water depth-to-wavelength ratios, *d/L* for all tests were in the range of transition water (0.04 to 0.5).

From the experiments conducted, the results obtained indicate that the system is a good wave attenuator as it is capable of dissipating most of the wave energy by breaking and internal friction over its stepped slope. The model is an effective dissipater rather than wave reflector. As number of rows increase, the wave attenuation ability increases. In conclusion, it has been proven to be better than any other type of floating breakwater.

Fousert (2006) as mention in the previous chapter studied the dynamics of wave attenuation. He studied and tested a model called Rectangular Floating Breakwater or ReFBreak model that proved theoretically that the floating breakwater is able to attenuate waves with periods up to 17.0 seconds when the structural layout is optimal. He also mentioned that the performance of the floating breakwaters does relate to the draft-with relation. Since the results and calculations are purely theoretical, further research and tests are necessary to investigate the influence of the irregular ocean waves on the performance of the floating breakwater. The study conducted focused on a floating breakwater with the purpose of protecting harbour activities. A floating breakwater have to be able to attenuate waves of the critical period range and applicable on several locations and conditions aside from being manageable, transportable, reusable and durable (Fousert, 2006).

2.2 THEORY OF WAVES

Water waves are disturbances caused by energy moving through water mass. Note that, only energy moves. In ocean, waves may travel thousands of kilometres before striking land. Waves often assumed to be sinusoidal but the actual shape is very complex. The disturbing forces include wind, underwater disturbance (earthquakes, landslides and volcanic eruption), changes in atmospheric pressure and gravitational pull by the sun or moon. The dominant restoring forces which calm the water surface are surface tension or capillary force and gravity.

The first effect of wind on water creates ripples or capillary waves which have wavelengths of less than 1.74 cm and its dominant restoring force is surface tension. As wind blows at higher velocity, capillary waves become gravity waves. Gravity waves have wavelengths exceeding 1.74 cm and their restoring force is gravity. They are also called wind-generated waves as they are elevated high enough above the surface of the water to provide good surface area for wind to push on. There are three factors which affect the wind wave development:-

a. Wind strength / speed
b. Wind duration
c. Fetch (the distance over which the wind blows).

In case where all three factors increase, the wave height, wavelength and wave period increases.

Gravity or wind waves are divided into two categories – seas and swells. Sea is the area in which wind driven waves are generated. Seas are often seen short-crested, choppy waves with mixed wavelength appearance. Most of the waves propagate in direction of wind blows. The waves have different wave heights, wavelengths and periods. Waves of long wavelength travel fastest in deep water, so the process of wave dispersion occurs.

Swells are waves that move beyond the area of wave generation. Long-crested wave move out and ahead of storm area having speed faster than wind speed outside storm area. The steepness of wave then decreases as they run over long distance with minimum energy loss. The waves then form group or trains of waves which travels at ½ the speed of individual waves.

To conclude, basically when wind blows, seas begin to appear in the generation area stretching along the fetch. Long-crested waves propagate creating swells having low steepness and travel over long distance with minimum energy loss. Finally, wave enters dissipation area where depth decreases and wave breaks causing dissipation of energy.

2.2.1 Wave Characteristics

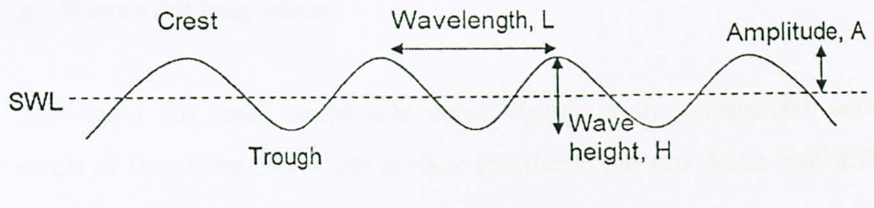


Figure 10: Wave characteristics sketch

Figure 9 above shows the characteristic of waves. Crest is the highest level or peak of the wave and trough is the lowest point. Wavelength, L is the horizontal distance of two successive waves either from crest to crest or trough to trough. The vertical distance from trough to crest is the wave height, H and the half of a wave height is called amplitude, A. The time for two successive waves to past a point or more exactly, the time for one wave length is noted as wave period, T while the number of waves passing a point per unit time is the inverse of period, *1/T* which is also known as the frequency, *f*. The wave steepness is the wave height-to-wavelength ratio which is given by *H/L*. When the wave steepness ratio, *H/L* is more than *1/7*, the wave breaks. The speed of wave propagation or celerity, $C = L/T$. Waves of almost the same period interfere and tend to travel together forming beats or wave groups. The speed of wave group is noted as C_G.

2.2.2 Small-amplitude Wave Theory

Airy (1845) wave theory is only applicable to waves with wave height smaller compared to the wavelength and water depth. It is referred to as linear or first order wave theory because of the simple assumptions made in its derivation.

Assumptions

a. The fluid is homogeneous and incompressible (constant density).
b. Surface area can be neglected.
c. Pressure at the free surface is uniform and constant.
d. The particular wave being considered does not interact with any other motions.
e. The seabed is horizontal, fixed, impermeable boundary.
f. Wave amplitude is small.
g. Waves are long crested.

The basis for small amplitude wave theory is the sinusoidal wave. The displacement of the sinusoidal water surface relative to the sea water level (SWL), □ may be described as

$$\eta = \frac{H}{2}\cos 2\pi\left(\frac{x}{L} - \frac{t}{T}\right) \tag{2.1}$$

where x is the distance measured along the horizontal axis and t is time. The wave celerity, c which is the speed at which the wave moves in the x-direction is the ratio of wavelength-by-wave period which is given by

$$C = \frac{L}{T} \tag{2.2}$$

Waves of almost the same period interface and tend to travel together forms beats or wave groups. The relation of velocity of wave propagation, C with the group velocity factor, n gives the speed of the wave group, C_G given by

$$C_G = nC \tag{2.3}$$

where

$$n = \frac{1}{2}\left[1 + \frac{4\pi d/L}{\sinh(4\pi d/L)}\right] \tag{2.4}$$

and

$n = 0.5$ for deep water,

$n = 1.0$ for shallow water, and

$0.5 < n < 1.0$ for transitional water.

Reeve (2004) states that the derivation of the Airy wave equations starts from the Laplace equation for irrotational flow of an ideal fluid. The equation is an expression of the continuity equation applied to a flow net and is given by

$$\underbrace{\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z}}_{\text{Continuity}} = 0 = \underbrace{\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial z^2}}_{\text{Laplace}}$$

where u is the velocity in the x-direction, w is the velocity in the z-direction, ϕ is the velocity potential and $u = \partial\phi/\partial x$, $w = \partial\phi/\partial z$.

The solution for ϕ which satisfies the Laplace equation throughout the body of the flow must satisfy the boundary conditions at the bed and the surface.

Assuming that the bed is horizontal and the vertical velocity, w is zero, and any particle on the surface most remain on the surface gives

$$w = \frac{\partial \eta}{\partial t} + \frac{\partial \eta}{\partial x} \qquad \text{at } z = \eta$$

and the (unsteady) Bernoulli's energy equation must be satisfied,

$$\frac{p}{\rho} + \frac{1}{2}\left(u^2 + w^2\right) + g\eta + \frac{\partial \phi}{\partial t} = C(t) \qquad \text{at } z = \eta$$

By assuming that $H<<L$ and $H<<d$, the linearised boundary conditions (in which the smaller, higher order and product tems are neglected) is obtained. The resulting kinematics and dynamic boundary equations are then applied at the still-water level, given by,

$$w = \frac{\partial \eta}{\partial t} \qquad \text{at } z = 0$$

and

$$g\eta + \frac{\partial \phi}{\partial t} = 0$$

The resulting solution for ϕ is,

$$\phi = -gH\left(\frac{T}{4\pi}\right)\frac{\cosh\left(\frac{2\pi}{L}\right)(d+z)}{\cosh\left(\frac{2\pi}{L}\right)d}\sin\left(\frac{2\pi x}{L} - \frac{2\pi t}{T}\right) \tag{2.5}$$

By substituting equation (2.5) into equation (2.1) gives wave celerity, C which is,

$$C = \left(\frac{gT}{2\pi}\right)\tanh\left(\frac{2\pi d}{L}\right) \tag{2.6a}$$

since wave number is $k = 2\pi/L$ and wave angular frequency is $\omega = 2\pi/T$, equation (2.6a) may be expressed as,

$$C = \left(\frac{g}{\omega}\right)\tanh(kd) \tag{2.6b}$$

Substituting c from equation (2.2) gives,

$$C = \frac{L}{T} = \frac{\omega}{k} = \left(\frac{g}{\omega}\right)\tanh(kd)$$

or

$$\omega^2 = gk\tanh(kd) \tag{2.6c}$$

which is known as the wave dispersion equation. Sorensen (1993), and Dean and Dalrymple (1991) gives the full derivation of the Airy wave equations.

Airy's wave theory classified waves by its relative depths, d. There are three depths considered – deep water, transitional water and shallow water. A wave is classified as deep water wave when its wavelength, L is more than half the water depth, $d/L > 1/2$. A shallow water wave is when $d/L < 1/25$. Hence, transitional water wave is when d/L ratio is between $1/2$ and $1/25$. For large water depth d, $\tanh(2\pi d/L) \to 1$ (2.7a) while for smaller d, $\tanh(2\pi d/L) \to 2\pi d/L$ (2.7b). By substituting equation (2.7a) and (2.7b) into equation (2.6a) the celerity c for waves according to the water depth is,

$$C = C_o = \frac{L}{T} = \frac{gT}{2\pi} \qquad \text{(deep water)} \tag{2.8a}$$

$$C = \frac{L}{T} = \frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right) \qquad \text{(transitional water)} \tag{2.8b}$$

$$C = \frac{L}{T} = \sqrt{gd} \qquad \text{(shallow water)} \qquad (2.8c)$$

and the wavelength is given by,

$$L = L_o = \frac{gT^2}{2\pi} = C_o T \qquad \text{(deep water)} \qquad (2.9a)$$

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \qquad \text{(transitional water)} \qquad (2.9b)$$

$$L = T\sqrt{gd} = CT \qquad \text{(shallow water)} \qquad (2.9c)$$

Forces from wind transfer its energy to the water which then forms waves. In deep water, water particles near the surface orbits in a circular motion making the surface waves a combination of longitudinal (back and forth) and transverse (up and down) wave motions. As waves propagate to more shallow water depths where the depth is less than half a wave length, the water particles' trajectory compressed forming an elliptical motion. The amplitude and magnitude of water particle displacement decrease with depth. As for deep water, the circular motion of water particles stop at $z = L_o/2$ while in shallow water, the elliptical motion is compressed further until water particles only moves longitudinal motions.
Chakrabarti (1987) expressed equation (2.5) as,

$$\phi = \frac{gH}{2\omega} \frac{\cosh ks}{\cosh kd} \sin\theta \qquad (2.10)$$

where $s = y + d$ and $\theta = k(x - Ct)$ with y acting as the positive upward direction of wave propagation.

Combining equation (2.10) and equation (2.6c) gives an alternated form for ϕ which is,

$$\phi = \frac{\pi H}{kT} \frac{\cosh ks}{\sinh kd} \sin\theta \tag{2.11}$$

By differentiating equation (2.11) with respect to x and y, the horizontal water-particle velocity is,

$$u = \frac{\pi H}{T} \frac{\cosh ks}{\cosh kd} \cos\theta \tag{2.12a}$$

and the vertical water-particle velocity is,

$$w = \frac{\pi H}{T} \frac{\sinh ks}{\sinh kd} \sin\theta \tag{2.12b}$$

or alternatively as,

$$u = \frac{H}{2} \frac{gk}{\omega} \frac{\cosh ks}{\cosh kd} \cos\theta \tag{2.12c}$$

$$w = \frac{H}{2} \frac{gk}{\omega} \frac{\sinh ks}{\cosh kd} \sin\theta \tag{2.12d}$$

The horizontal and vertical water-particle accelerations are given by,

$$a_x = \frac{gkH}{2} \frac{\cosh ks}{\cosh kd} \sin\theta \tag{2.13a}$$

$$a_z = -\frac{gkH}{2} \frac{\sinh ks}{\cosh kd} \cos\theta \tag{2.13b}$$

The horizontal and vertical displacements of the water particle about its mean position are obtained by the integration of u and w with respect to time t, which gives,

$$\xi = -\frac{H}{2}\frac{\cosh ks}{\sinh kd}\sin\theta \tag{2.14a}$$

$$\zeta = \frac{H}{2}\frac{\sinh ks}{\sinh kd}\cos\theta \tag{2.14b}$$

All the equations have three components. The first is a magnitude term, the second describes the variation with depth and is a function relative depth and the third is a cyclic term containing the phase information (Reeve, 2004). By substituting $s = y + d$, $k = 2\pi/L$ and $\omega = 2\pi/T$ into equation (2.12c), (2.12d), (2.13a), (2.13b), (2.14a) and (2.14b), the horizontal and vertical velocities, accelerations and displacements according to the water depths may be obtained (see summary in Appendix A).

The energy contained within a wave is the energy per unit area of the sea surface which consist of the sum of the potential energy E_P, kinetic energy E_K and surface tension (usually ignored) energies of all the particles within a wavelength. The total energy E is given by,

$$E = \frac{1}{8}\rho g H^2 \tag{2.15}$$

The wave power, P is obtained by summing the potential, kinetic and pressure energies and multiplying by the particle velocity in the x-direction for all particles in the wave which gives the rate of transmission of wave energy given by,

$$P = \frac{\rho g H^2}{8}\frac{C}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right)$$

$$P = EC_G \tag{2.16}$$

2.2.3 Wave Processes

Waves enter the transitional depth region as they approach a shoreline, from deep water to shallow water, which cause the wave to transform. This region affects the motions of waves which cause the reduction of the wave celerity and wavelength which alters the direction of wave crests and wave height with wave energy dissipated by seabed friction which finally ends with wave breaking. There are six main processes affecting waves moving from deep to shallow water, which is,

a. Shoaling
b. Breaking
c. Refraction
d. Diffraction
e. Reflection
f. Wave run-up

Shoaling occurs when the presence of the seabed or beach affect the celerity of the wave energy. This effect may be to stretch or concentrate the energy, so it may increase or decrease the wave amplitude. The wave heights and wavelength may change (while wave period remains constant as wave propagates), but the wave fronts remain parallel to the bottom contours. The change in wave amplitude is measured by the shoaling factor, K_s which is given by,

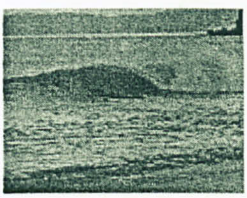
$$K_s = \frac{H}{H_o} = \sqrt{\frac{C}{C\left[1 + \frac{4\pi d/L}{\sinh(4\pi d/L)}\right]}} \tag{2.17}$$

Wave breaking causes reduction in wave energy and wave height in the surf zone. This is due to the limited water depth. It is dominant in the surf zone which is the region extending from the seaward boundary of wave breaking to the limit of wave up-rush. There are several parameters considered in wave breaking.

a. Breaker height, H_b – the maximum limit of wave height above which the wave becomes unstable and breaks. It is the vertical distance from the crest of the breaker to the level of the trough ahead of the breaker.
b. Breaker wave length, L_b – the horizontal distance between two successive breakers.
c. Breaker period, T_b – the time in seconds between successive breakers which is always the same as the deepwater wave period.
d. Depth of breaking, d_b- the depth of the water at the point of breaking.

Wave will break when there is a limit to wave steepness and on the wave height to water depth ratio. This means, when steepness H/L exceeds $1/7$, wave breaks. There are two types of breaking waves – open-water whitecaps (deepwater) and near-shore breaker (shallow or transitional water). The high winds increases the wave height faster than the wavelength can increase. When wave gets too tall to support itself, the wave breaks and cause whitecaps in the deeper region of the sea. Near-shore breaker occurs when the cycloid motion of water particles of waves begin to touch the sea bottom. The motion becomes disorganised and cause disturbance to the bottom sediments. The friction and turbulence underwater slows the wave and shortens the wavelength, this causing the wave to become steeper. When water depth $d_b = 1.28H_b$, the wave breaks. These breakers disturb the bottom sediments which results in erosion and sediment transport. There are three main types of breakers (see Table 3).

Table 3: Breaker types

Types	Descriptions
Spilling breaker 	Very flat, nearly horizontal to beach. Occurs at any time. Breaking happens far from shore and the surf gently rolls over the front of waves. Water at crest of waves creates foam as it spills down the face of the wave. Swimmers are used to this kind of waves. Once in a while the wave creates a tunnel effect ("Tube" or "Pipe").
Plunging breaker 	Moderate steep beach. Occur at high tide. The most violent and dangerous wave but loved by surfers. Wave curls over forming a tunnel until it breaks and plunges down in a violent tumbling action causing high splash and scour into sea bottom. Commonly associated with swells that approach the beach with much longer wavelength.
Surging breaker 	Very steep beach. Occur on rocky shorelines, jetty or manmade seawall. Wave crest remains unbroken and the front face of wave advances up the steep beach with minor breaking. Entire face of wave usually displays churning water and produces foam. No actual curl developed. Known for their destructive nature.

Breaker type can be determined from surf similarity parameter, ζ which is given by,

$$\zeta = \frac{\tan\beta}{\sqrt{H_o/L_o}} \tag{2.18}$$

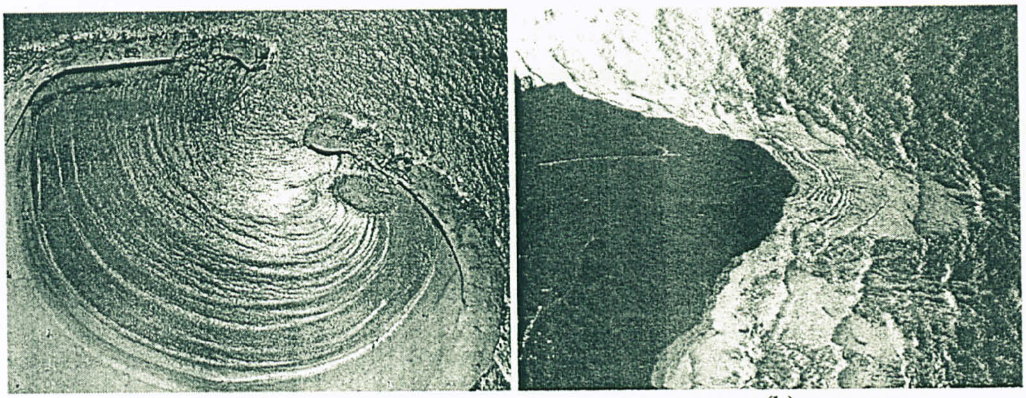
Spilling breaker: $\zeta < 0.5$

Plunging breaker: $0.5 < \zeta < 3.3$

Surging breaker: $\zeta > 3.3$

where H_o is the deepwater wave height, L_o is the deepwater wavelength and $tan\,\beta$ is the beach slope.

Wave refraction (see Figure 11) occurs when wave approaches the shore at an angle. It is the bending effect of wave crest in order to align to the bottom contours of bathymetry as waves are moving over different depths. There are two elements considered in refraction – wave front and wave orthogonal. Wave front is the curve in the horizontal plane through adjacent crest points while wave orthogonal or wave ray is the path or curves perpendicular to the wave fronts at every point.



(a) (b)

Figure 11: Wave Processes - Wave refraction (a) diverge, (b) converge

The waves converge or diverge of wave rays depends on the shape f the topography which influence the direction of wave travel. The refraction happens to slow down, and the wave fronts bends or turns closer to a parallel position relative to the shape of the shorelines. At points or promontories projecting into the sea, wave fronts on both sides turn towards the point. Great amount of energy will be focused toward the point which causes it to wear away over time. Headlands or submarine ridges face converging rays while bay or submarine canyon faces diverging rays. The wave heights are higher at a headland compared to at bay. Wave refraction analysis provides near shore transformation of waves from deepwater condition to shallow water and the shallow water wave height and distribution of wave energy along the coast results in convergence or divergence of wave energy which may cause erosion or deposition of beach materials. The refracted wave height, H_i is given by,

$$H_i = H_o K_s K_r \tag{2.19}$$

where,

$$K_s = \frac{H}{H_o^{'}} \qquad \text{(shoaling coefficient)}$$

$$K_r = \sqrt{\frac{B_o}{B}} = \sqrt{\frac{\cos\alpha_o}{\cos\alpha}} \qquad \text{(refraction coefficient)}$$

Wave reflection occurs when wave energy is reflected as the waves hit into a rigid obstruction such as breakwater, seawall, cliff etc. This is especially obvious where the surface is a smooth vertical wall. The degree of wave reflection is defined by the reflection the reflection coefficient, C_R expressed by,

$$C_R = \frac{H_r}{H_i} \qquad (2.20)$$

where H_r is the reflected wave height and H_i is the incident wave height. Total reflection occurs when $C_R = 1$. When no reflection occurs, $C_R = 0$. Partial reflection occurs when C_R lies in between 1.0 and 0.

Wave diffraction (see Figure 12) is a process where wave energy is laterally transferred along a wave crest as the wave bends around an obstruction. As wave crest passes the tip of the obstacle, wave crests bend and spread the wave energy in the shadow zone (leeside of breakwater). This results in the decrease of wave height. Diffraction plays an important role in the development of tombolo. The height of diffracted wave can be determined by using equation (2.21).

$$H_d = K_d H_i \qquad (2.21)$$

where H_d = diffracted wave height, K_d = diffraction coefficient and $K_d = f(\theta, \beta, r/L)$.

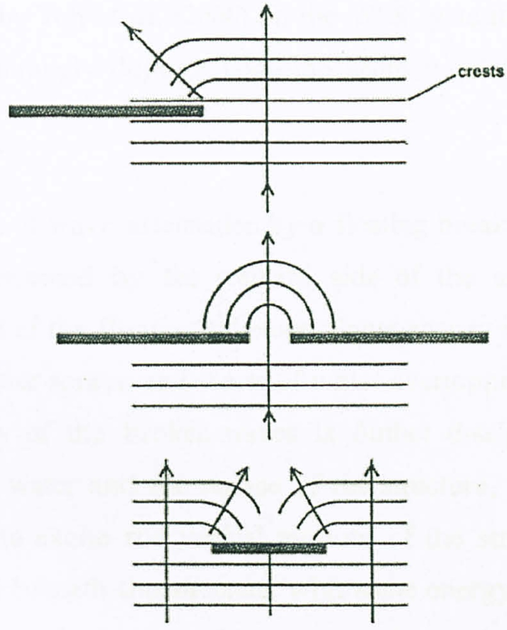


Figure 12: Wave processes - Wave diffraction

2.2.4 Wave Transmission

The main factors considered in the attenuation of waves by floating breakwaters are the breakwater width *B*, breakwater draft *D*, wave steepness *H/L*, and water depth *d*. The transmitted wave height H_t can be associated with the breakwater width and draft while the incident wave height H_i condition depends on the period, wavelength etc.

When discussing wave transmission by floating breakwater, 3 main coefficients are taken into account. The 3 coefficients are coefficient of transmission C_T, coefficient of reflection C_R and total energy loss noted as C_L. The coefficients took into account a few dimensionless parameters such as relative width, *B/L*; relative draft, *D/L*; wave steepness parameter, H_i/gT^2; and relative depth, d/gT^2.

Coefficient of transmission, $C_T = H_t / H_i$

reflection, $C_R = H_r / H_i$

loss of energy, $C_L = (1 - C_R^2 - C_T^2)^{0.5}$

where H_r = reflected wave height

H_t = transmitted wave height

H_i = incident wave height

Studies done by Teh et al. (2006) on the WSS system shows that the degree of wave attenuation strongly depends upon the geometrical factors of the structure and wave conditions.

In the process of wave attenuation by a floating breakwater, a portion of the wave energy is intercepted by the seaward side of the structure, posing wave reflection at the front of the floating structure. Some energy is lost in form of wave breaking and may cause sprays and sheets of water overtopping the seaward arm of the structure. Energy of the broken waves is further dissipated through friction between the running water and the surface of the structure, heat and sound. Some energy is also used to excite the vertical motions of the structure. The remaining energy is transmitted beneath the structure, with some energy dissipation due to the turbulence that occurs at the bottom of the structure, before it reaches the leeside and forms a transmitted wave in reduced height.

Some places or location requires a low wave reflection. Locations where boats and vessels are involved in several activities, wakes caused by reflected wave are undesirable. The reflection of waves becomes more significant when the ratio of breakwater draft-to-water depth D/d is larger. Greater D/d ratio indicates that a large portion of water column at test section is occupied by the draft of the breakwater, thus reflecting more wave energy to the opposite direction.

A portion of wave energy is intercepted and reflected by the seaward draft and freeboard of the floating structure. The rest of the wave energy will be transferred under or over the structure reforming transmitted waves at the leeside of the structure. More energy passes below the structure when the wave period is longer. This is because the longer period wave energies are distributed more uniformly in the water column.

The remaining wave energies are dissipated through the act of friction between water and the surface of the structure. The shape of the structure should allow most of the wave energy gets dissipated mainly through breaking process at the seaward side, friction between the flowing water and surface of the structure, and turbulence formed at the bottom of the floating structure; thereby taking out a significant energy from the incoming waves.

2.3 OVERVIEW OF EXISTING FLOATING BREAKWATER

Most breakwaters used in Malaysia are of fixed type. The Costal Engineering Department under the Department of Irrigation and Drainage (DID) of Sarawak report shows the list of projects under the 9th Malaysian plan. Almost all projects for coastal protection uses rock revetment and concrete blocks (see Table 4).

Table 4: List of projects under the 9th Malaysian plan (DID Sarawak)

Location of the Project	Year of Completion	Length of Protection Works	Type of Protection Works
Kampung Rejang, Mukah	2006	580 m	Rock Revetment
Sungai Serpan, Samarahan	2006	500 m	Rock Revetment
Jalan Miri-Kuala Baram (Pan Borneo Highway), Miri	2006	1.9 km	Rock Revetment
Kampung Santubong, Kuching	2007	390 m	Concrete Blocks
Pantai Kampung Punang (Phase 2), Lawas, Limbang	2007	210 m	Rock Revetment
Marriot Resort & Spa, Miri	2007	550 m 170 m	Rock Revetment Concrete Blocks

Nevertheless, this new technology has penetrated Malaysian market as it is widely used is marinas especially in Langkawi and Port Dickson. This chapter will discuss two real breakwaters which is in Telaga Harbour Marina, Langkawi and Cypremort Point State Park, LA. At the end of this chapter is a summary of existing floating breakwaters and pontoons (see Table 5).

2.3.1 Telaga Harbour Marina, Langkawi

Located in the natural cove of Pantai Kok, Langkawi the marina is a brand new gateway and destination for many yachts plying the region. The safe sheltered harbour has evolved from a small fishing village to a township equip with all sorts of facilities and services. It is developed by the Langkawi Development Authority (LADA) and now operated and managed by Telaga Harbour Sdn Bhd. A basin area of 27 acres was created and designed for public berthing of craft in various sizes.

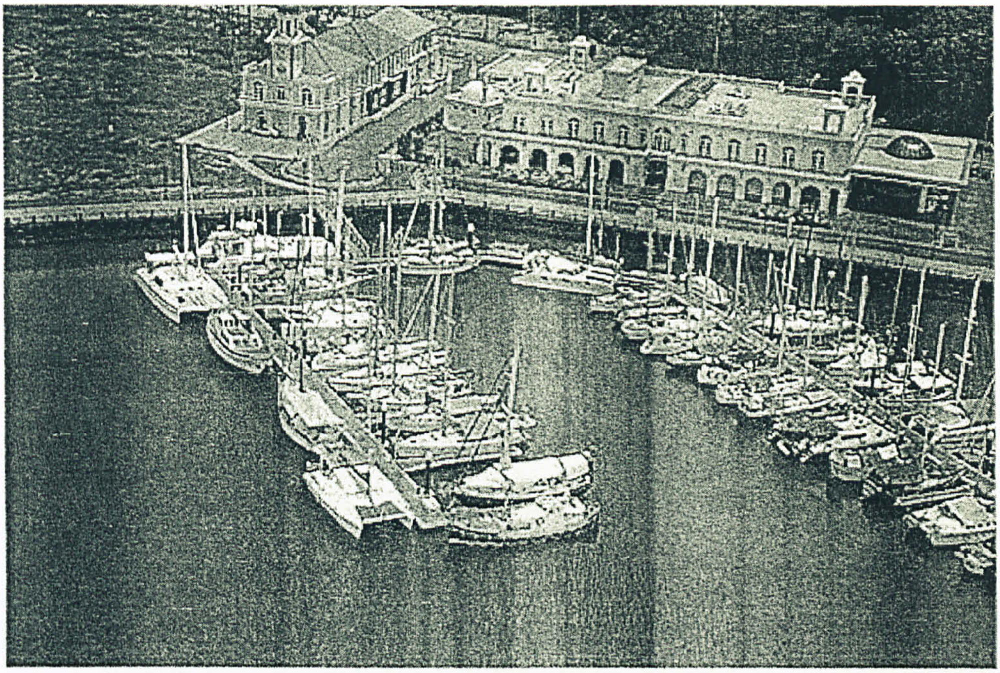


Figure 13: Berth Layout, Telaga Harbour, Langkawi

The marina has floating pontoons which were newly installed since the existing ones were destroyed in the December 2004 tsunami. Designed and constructed by a French company based in Singapore, the pontoons are installed with fingers of sizes 8 x 10 m and 7 x 12 m (see Figure 13 and Figure 14).

The pontoons were made of aluminium frame coupled with plastic floats and timber decks. The aluminium frames was fabricated in France before it is been brought to Malaysia. The plastic floats which are made of High Density Polyethylene (HDPE) and the timber decks are locally made. Polyurethane (PU) was stuffed into the hollow HDPE casing to enhance the floatation of the material. Each pontoon measures 12 feet in length and was transported to site using standard haulage containers.

The main frame of the pontoons was aluminium. Each pontoon is connected by 2 pieces of high tension rubber which were fitted in between of 2 pontoon edges. The deck is made of local wood called 'Balau'.

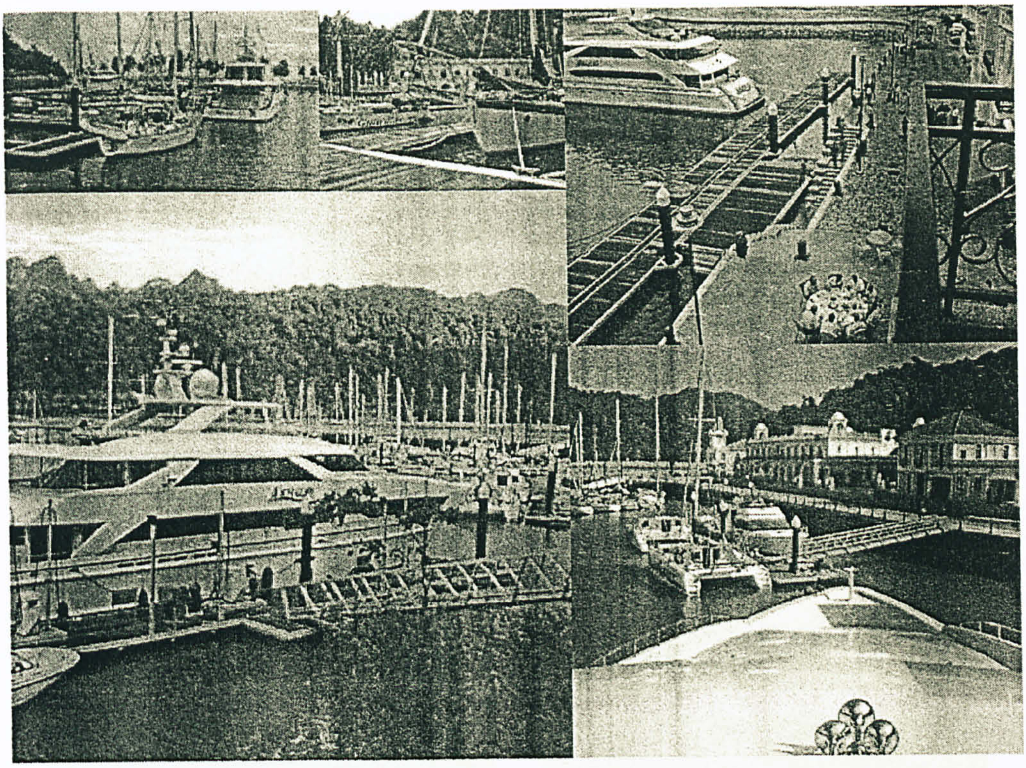


Figure 14: Pontoons at Telaga Harbour, Langkawi

2.3.2 Cypremort Point State Park, LA

On November 12, 2003, Wave Dispersion Technologies (WDT) announced the complete installation of a 1500 ft floating breakwater for Cypremort Point State Park Beach Erosion Control Project in Cypremort Point, LA. It was a part of the restoration plan since the damage caused by a previous hurricane.

WhisprWave® Breakwaters / Barrier which recently passed the Hurricane Isabel tests was believed to have sustained winds up to 80 mph with gusts of up to 100 mph without damage. The WhisprWave® is a patented modular marine floating breakwater highly engineered to provide shoreline beach erosion control. Each modules is assembled similar to LEGO's® or building blocks.

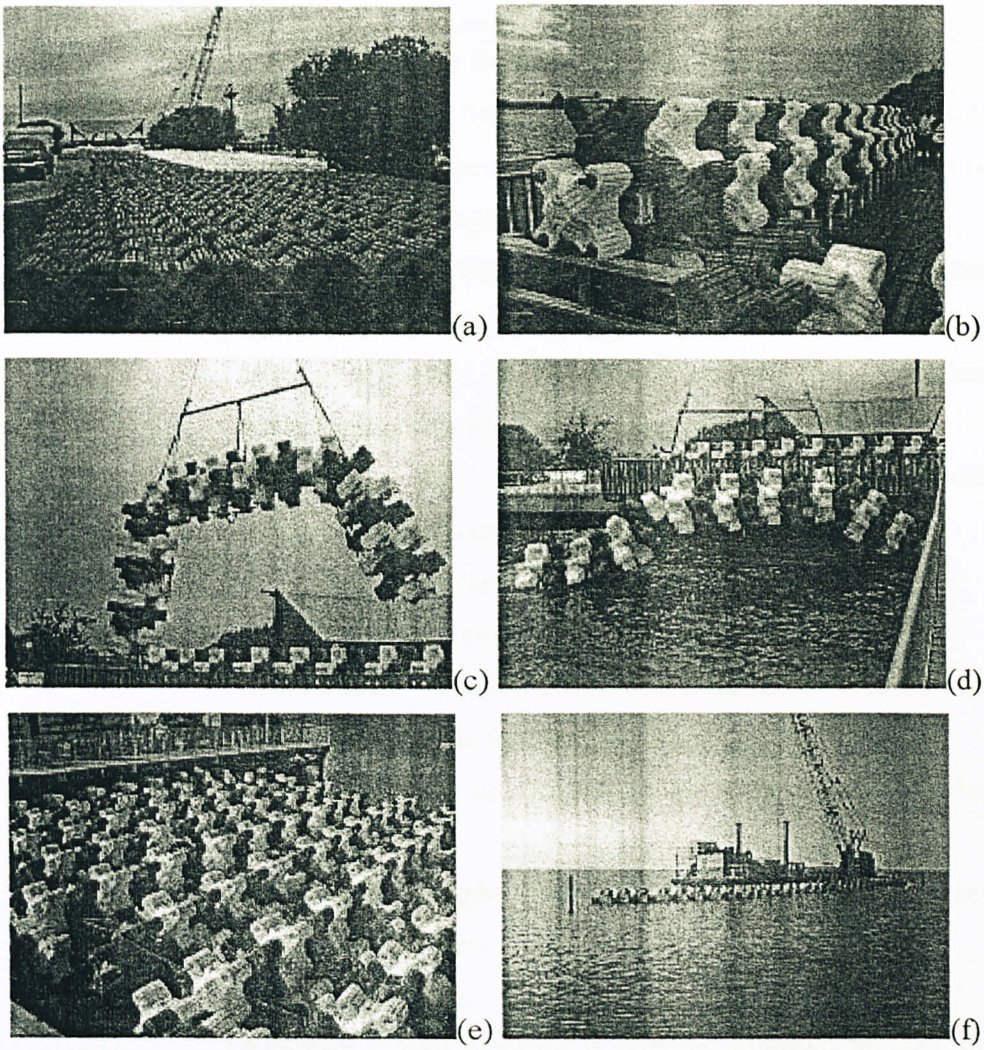


Figure 15: Cypremort Point Park, LA floating breakwater installation (a) Raw materials of floating modules, (b) Assembly, (c) Repositioning of floating breakwater, (d) Launching, (e) Floating breakwater corralled, (f) Floating breakwater installed

The module is a highly engineered polygon shaped object (see Figure 15) made of high-density polyethylene. A standard module weighs about 36 lbs when empty. The design enables each module to be filled with water to adjust its buoyancy. Each module is connected by a system of EPDM rubber cables, marine grade hardware and stainless steel anchoring harness.

The WhisprWave® floating breakwater installed in Cypremort Point State Park in LA consists of approximately 1500 modules measuring 2 ft in height, width and length.

Table 5: Summary of existing floating breakwater

Floating Breakwater	
FDN U-block FBW	**Advantages** – flexible, short construction time, low maintenance requirements, little influence on the transport of sediment and low cost. **Function** – floating breakwater and a quay. Economic solution for marinas. **Design** – withstand 2m high and 6sec period waves. Custom-made design can withstand 8m high waves. **Material** – B35 reinforced concrete ($35N/mm^2$) with polystyrene blocks core ($0.15kN/m^3$). **Design life** – 30 years. **Effectiveness** – normal 100%, storm 80%. **Connections** – flexible rubber and steel tested to resist high pressure and tensile forces up to 30 tons. **Mooring** – piles or chains / cables with concrete anchor blocks. **Dimension** – length: 25m / 82 feet, width: 4.5m / 15 feet, height: 4m / 13 feet. **Weight** – 135 tons
Marinetek pontoons / breakwaters **- Heavy Duty Pontoons** **- Super Yacht Pontoons** **- Timber Pontoons** **- Aluminium Pontoons**	**Function** – boat mooring in marinas, overpass bridges and landing stages. **Advantages** – strong and maintenance-free with high loading capacity. Light and easy to handle for timber and aluminium pontoons. **Design life** – very long (number of years not mentioned). **Dimensions (width)** – Heavy duty pontoons: 2.7m, 3.3m and 4.3m. Timber pontoons: 1.8m or 2.2m. **Material** – strong heavy-duty floats (+ different kinds of concrete coatings, softwood or hard wood decking, cable ducts and service channels and fixing rails for adjustment of long fingers). Timber with concrete floats or plastic floats. **Connections** – flexible rubber and steel joints at corner and

	sides if required. **Mooring** – mooring lines / chain, piles or sea flex.
Floating Pontoon (Admiral Marina, Port Dickson)	**Anchorage** – piles. **Connections** – wooden planks, bolts. **Size** – Type A: 3.6m x 2.4m x 0.85m. Type B: 3.6m x 1.2m x 0.85m. Type C: 4.2m x 1.8m x 0.85m. Type D: 2.4m x 3.0m x 0.85m. **Materials** – fibre reinforced concrete with core of foam. **Year of Installation** – 1998 **Free Board** – 0.35m
Floating Pontoon (Rebak Marina, Langkawi)	**Materials** – aluminium and wooden decks, HDPE floats (+ accessories such as fenders and wooden decking). **Function** – marina, berth for yachts mooring. **Connection** – neoprene rubber block.
Floating Pontoon – L-shaped, MTC Pontoons, Fiberglass Floats (Royal Langkawi Yacht Club)	**Function** – berth, walkway and secondary breakwater. **Year of Installation** – somewhere in 1997. **Design** – withstand waves up to 0.6m high. **Material** – concrete with core of foam; white fibreglass with polystyrene foam core, aluminium frames and rubber fenders / synthetic fenders; HDPE and marine grade aluminium. **Mooring** – steel chains with 3tons of block.

CHAPTER 3
METHODOLOGY

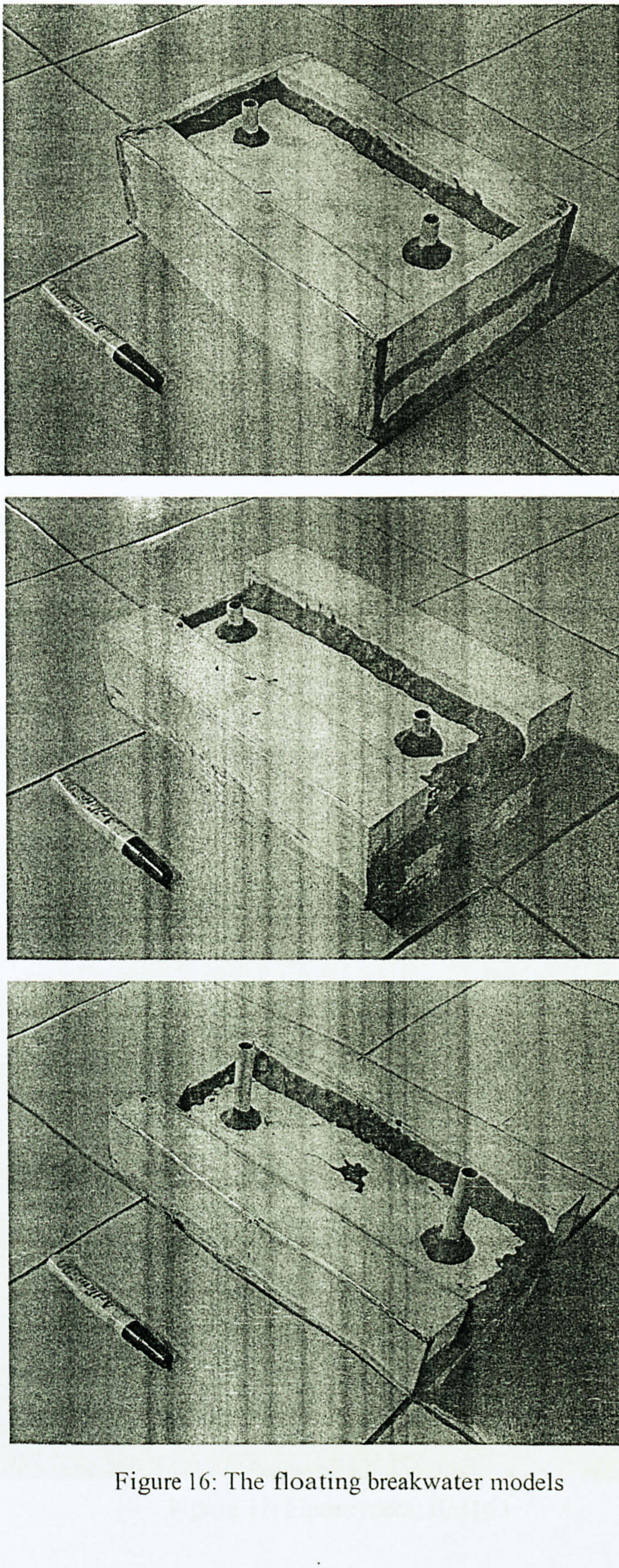
Series of experiments were conducted in a wave flume at the Hydraulics Laboratory in Universiti Teknologi PETRONAS, Tronoh. All three models were tested against a range of wave period, T in two water depths, d. Results from experiments was recorded and the parameters taken are the incident wave heights, H_i, the reflected wave height, H_r, and the transmitted wave height, H_t.

3.1 FLOATING BREAKWATER MODELS

Three models were fabricated for the project. The models were built according to the models used in the experiments done by Teh *et al.* (2007). The models (see Figure 16) are modified version of the Wave Suppress System (WSS) namely, M1, M2 and M3.

All three models were made of wood, painted with waterproof paint and sealed with *Liquid Sealer* to make sure that the models are water proof. The models are basically hollow-boxes with size of 100 mm high, 200 mm wide and 300 mm long. All four models are symmetric on all three planes.

The original WSS model has only one anchoring system which is a pile, penetrating through the centre of the model. In this study, the models were built with two hollow steel pipes having internal diameter of 15 mm, penetrates each models, approximately 50 mm for each side. The models are fixed to the bottom of the flume by steel rod which acts as piles and cables acting as mooring system. The cables were fixed to the models by hooks screwed to the four bottom edge of the model.



M1

M2

M3

Figure 16: The floating breakwater models

Floating breakwater model M1 is a basic box models which was fabricated as a control model. Floating breakwater model M2 was build according to the original WSS model. The model has a pair of arms on its top and bottom having the width of 50 mm running through the *z*-axis of the model. These arms form step-like sides. Floating breakwater model M3 was build according to the WSS – GEN-2 model with 45 degree slope at each bottom-side of the structure. M2 have a pair of arms on the top with 40 mm width and the bottom with 20 mm width running along the *z*-axis of the structure. All three models have a pair of hollow steel rods penetrating through at approximately 50 mm from each side.

3.2 LABORATORY EQUIPMENT AND INSTRUMENTATION

The flume model HM162 (see Figure 17) is 12 m long, 0.3 m wide and 0.45 m deep. The flume is built with rigid steel bed and clear glass panels on both sides. Clear glass panels allow first hand observations to any fluctuation of water levels in the flume during experiments.

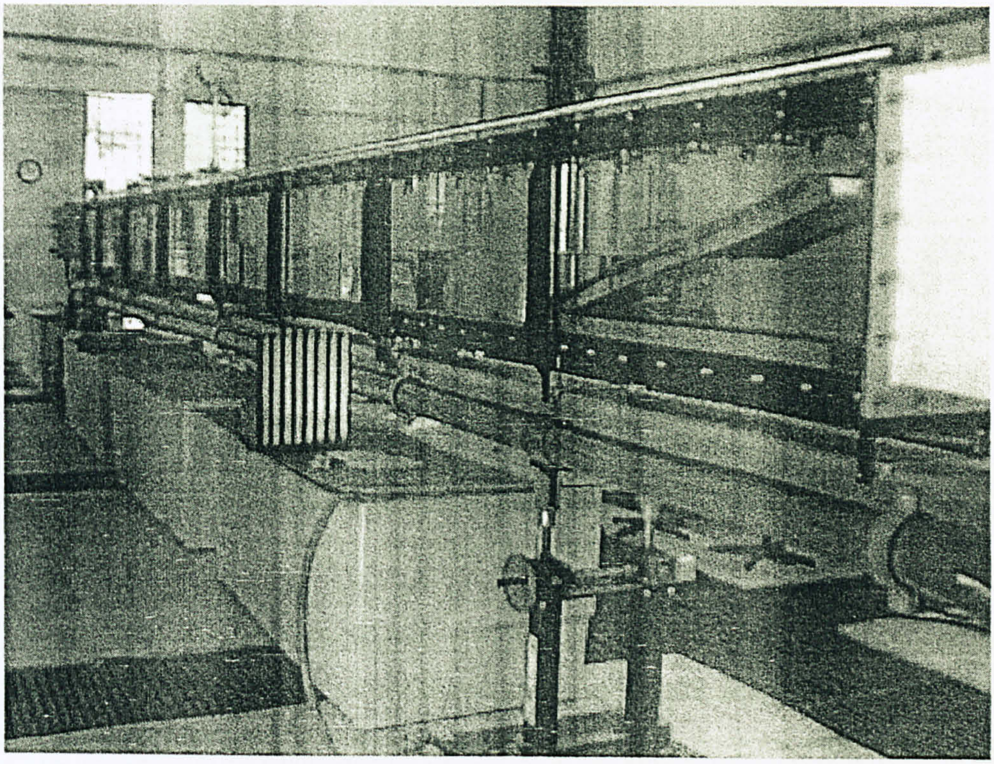


Figure 17: Flume model HM163

The flume was subjected to a steady monochromatic non-breaking wave generated by a flap-type wave maker (see Figure 17) installed at one end of the flume. The wave maker's frequency is controlled by the frequency knob at the control box, just beside the wave maker section. This frequency changes the speed of the 'flapper' or paddle which is connecting to a rotating circular disc by a push rod bolted at each side. There were three adjustment stokes on the circular disc – 80 mm, 140 mm and 200 mm. The push rod was set to 200 mm stroke adjustment throughout the experiment. The strokes frequency is controlled by the 10-gear potentiometer used to adjust the rotation speed of the circular disc. The maximum rotation speed is 114 rpm, varies linearly with minimum speed of 0 rpm.

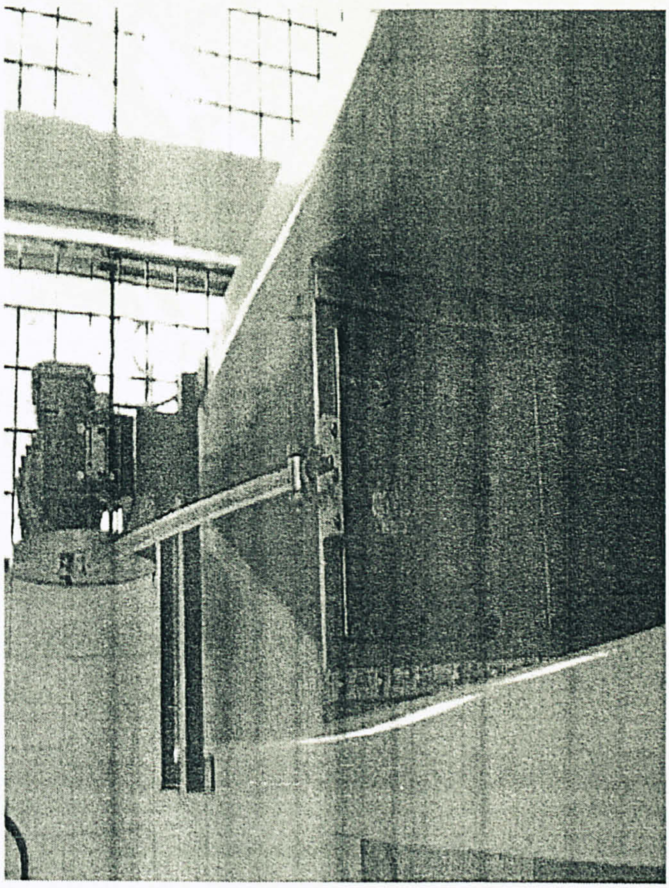


Figure 18: Flap-type wave maker

A wave absorber (see Figure 18) was installed at the opposite end of the flume to reduce the effects of reflected waves in the flume. The wave absorber consists of red and green wire mesh of 3.6 square metres lying on a plane at a slope of approximately 15 degrees.

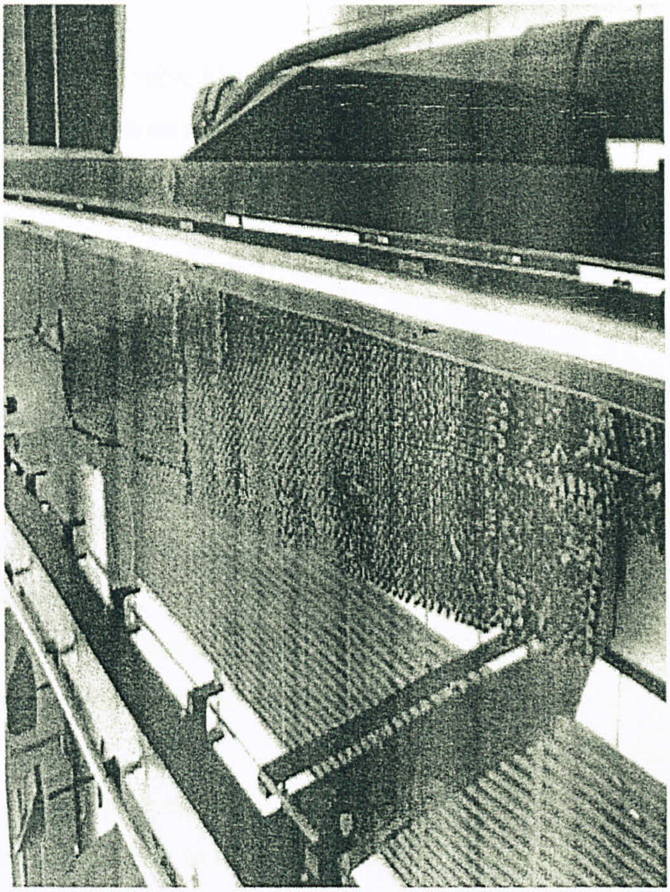


Figure 19: Wave absorber

3.2.1 Flume Details, Handling Procedure and Hazards

Details

Model no.: HM163

Location: Hydraulics Laboratory (Block J), Universiti Teknologi PETRONAS

Supplier: Maluri Sdn Bhd

To prepare flume

1. Switch on the 3 phase power supply.
2. Turn on the main system at the panel board.
3. Wait until the system shows 'OK' on the flow rate digital meter.
4. Switch on the water pump by turning knob to second step (delta).
5. Open the valve slowly to allow the water flow through the flume.
6. Run experiments.

Shutdown of flume

1. Close water pump valve slowly.
2. Switch off the main switch at the control panel of the flume.
3. Switch off the 3 phase switch.
4. Cleanup.

Hazards

Sequence of basic job steps

Climb up to the top water container to make or set water depth reading using the point gauge.

Potential accident

1. Falling due to unbalance.
2. Slip during climbing due to slippery surface.

Recommended safe job procedure

1. Use aluminium ladder to climb on to the water container.
2. Wear proper shoes.
3. Wear apron.

3.3 WAVE PERIOD

Wave period, noted by T is the time duration for two successive waves to pass through a point. The wave period used in the experiments for this study is 0.81, 0.87, 0.93, 0.99, 1.04, 1.10, 1.15, 1.21, 1.26, 1.31 and 1.37 seconds. The wave period is set by the frequency knob at the control box of the flume. The wave period determines the incident wave height, H_i and the wavelength, L used throughout the experiments.

The wave period, T was obtained from the different strokes set by the frequency. As the frequency of the wave maker does not use the term $f = 1/T$, tests were conducted to obtain the correspondence between the needed experimental wave period, T and the frequencies of the flume. The time for 5 to 10 cycles the oscillation of the flap-type wave maker and the complete cycle of the circular disk were measured for frequencies ranging from 15 to 95 rpm with increments of 5 rpm to obtain the wave period, T. This process was repeated three times in water depths of 200 mm and 300 mm to get the average value which gives the value of T.

3.4 INCIDENT WAVE HEIGHT

The wave heights, H_i were determined manually through obvious observation of the fluctuation in the flume. The maximum and minimum level reached by the waterline were marked, measured and recorded. These experiments were conducted without any of the floating breakwater model in the flume. The values obtained were used as the incident wave height. During this observation, the reflection of waves was neglected i.e. assuming no reflection wave occurred in the flume. After calibrations were done, a series of tests were conducted in order to obtain the incident wave height for wave period needed in the experiment in water depths of 200 mm and 300 mm.

3.5 EXPERIMENTAL STUDIES ON THE FLOATING BREAKWATER MODELS

Twelve sets of experiments were conducted for this study. Each model was tested in two different water depths, 200 mm and 300 mm; and two anchoring systems, pile and cable. The total experiment conducted throughout this study is summarized in Table 9 in Chapter 4.

The models were placed approximately 7 metres from the wave maker. The flume was filled with the required water depth and the frequency needed for the tests were set at the frequency knob at the control box of the flume. The measurements for wave heights were taken at the leeward side of the model. Measurements recorded for the incident wave heights were obtained without the model in the flume gives the height of the wave approaching the models i.e. the incident wave height, H_i. The values obtained at the seaward side of the model gives the height of waves behind the model i.e. the transmitted wave height, H_t.

The evaluation of the performance of each floating breakwater models were determined by the ability f each model to transmit minimum energy at the leeward side of the floating breakwater model. This is obtained by comparing the wave height of incident waves (at the seaward side of the model) and the transmitted waves (at the seaward side of the model). This gives the value of H_i and H_t. The ratio of transmitted-to-incident wave height was then computed in order to get the coefficient of transmission, C_T given by equation 3.1. The lesser value of C_T shows the high performance of the floating breakwater model in attenuating waves.

Transmission coefficient, $$C_T = \frac{H_t}{H_i} \tag{3.1}$$

CHAPTER 4

RESULT AND DISCUSSION

This chapter presents all results obtained from the series of experiments conducted throughout the study. Theoretical calculation of the stability of each models were presented in detail. Records from experiments on determining the frequency and wave period for incident wave height is also presented. Result from the experiments done for the three models were analyzed by comparing the models in terms of the performance in different water depth and different anchoring system. Graphs are available for comparison.

4.1 STABILITY OF THE FLOATING BREAKWATER MODELS

The stability of a floating structure depends on the geometry of body and density of fluid. It is known that the weight of displaced fluid equals to the total weight of the body. This gives the draft of the body when it is freely floating on a body of fluid which in this case, water. The stability of each floating breakwater models used in this experiment was determined by calculating the Metacentric Height which is noted by *GM*.

For a body to remain stable, without any other structures other than the body itself, the metacentre, *M* has to lie above the centre of gravity, *G*. This means, the value of *GM* is positive. If the metacentre, *M* lies under the centre of gravity, *G*, it will give *GM* a negative value, hence, the body is unstable. This *GM* value is obtained from;

$$GM = BM - BG \qquad (4.1)$$

To assess the stability of all three floating breakwater, the location of the centre of gravity, G is identified for each models. The location of the centre of buoyancy, B, which is the centriod of the displaced volume or in other words, the centroid of the immersed part of the body, is then identified. The distance of B and G gives the value of BG.

The value of BM is obtained using $BM = I / V_S$, where I is the 2nd moment of area of the plan section of the body where it cuts the waterline, and V_S is the volume of the submerged part of the body. In this case, since all models' basic shape is rectangular box, I is taken as $I = bd^3/12$.

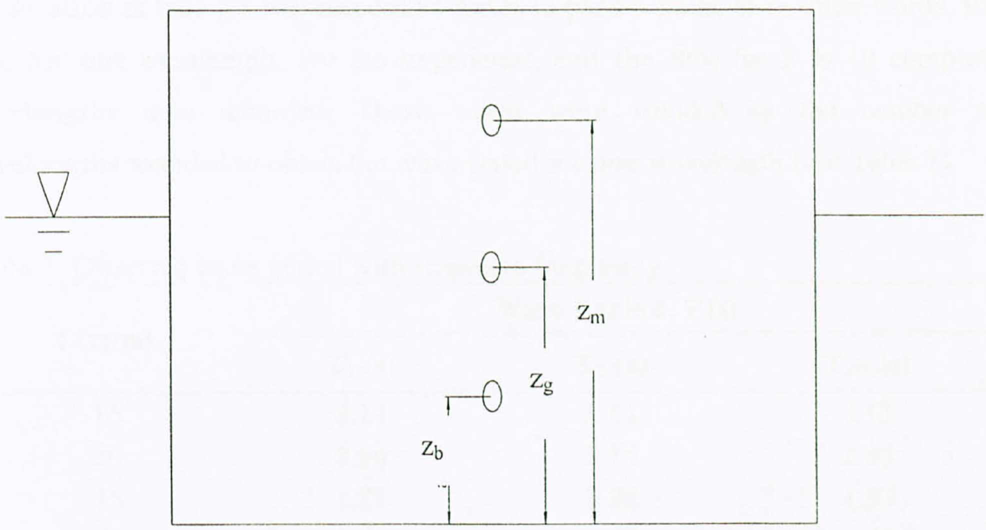


Figure 20: The sketch location of M, G and B on a rectangular floating structure

Table 6: Results on calculation and experimental stability of the floating breakwater models

Models	Units	M1	M2	M3
G	cm	5.00	4.76	8.75
B	cm	3.73	2.18	4.50
BG =G-B	**cm**	**1.27**	**2.58**	**4.25**
I	cm^4	20,000.00	19,405.98	20,000.00
V_S	cm^3	3,150.00	1,830.00	3,600.00
BM =I/V_S	**cm**	**6.35**	**10.60**	**5.56**
GM =BM-BG	**cm**	**5.08**	**8.02**	**1.31**
Experimental Condition	-	Stable	Stable	Stable

From this it can be conclude that the stability depends on the location of *M*, *G*, and *B* (see Figure 20). The calculations made proved that the floating breakwater models – M1, M2 and M3, are stable theoretically (see Table 6). After the fabrication of the models was done, all three models were tested by freely floating all models in the flume. All models were stable.

4.2 DETERMINATION OF WAVE PERIOD

A simple experiment was conducted to determine the wave period, T at different frequency strokes as set by the flume. In coastal engineering, wave period is the duration or time for two successive waves to pass a point, or in other words, the time for one wavelength. For the experiment, and the time for 5 to 10 complete wavelengths were recorded. These values were divided by the number of wavelengths recorded to obtain the wave period for one wavelength (see Table 7).

Table 7: Observed wave period with respect to frequency

f (rpm)	Wave Period, T (s)		
	T_1 (s)	T_2 (s)	T_{ave} (s)
15	3.14	3.11	3.13
20	2.54	2.15	2.35
25	1.81	1.85	1.83
30	1.50	1.44	1.47
35	1.36	1.31	1.33
40	1.23	1.16	1.19
45	1.00	1.08	1.04
50	1.00	1.02	1.01
55	0.88	0.89	0.88
60	0.79	0.76	0.77
65	0.70	0.64	0.67
70	0.69	0.58	0.64
75	0.61	0.56	0.59
80	0.55	0.55	0.55
85	0.48	0.46	0.47
90	0.44	0.44	0.44

For this study, the stroke adjustment is fixed at 200 mm. Studies done by C. Lee (2006) has proven that the stroke adjustments does not influence the wave period. The values obtained are then plotted into a graph of wave period, T versus stroke frequency, f (see Figure 21). An equation which shows the relationship of the wave period, T and the stroke frequency, f, is given by;

$$T = 57.272 f^{-1.0613} \tag{4.2}$$

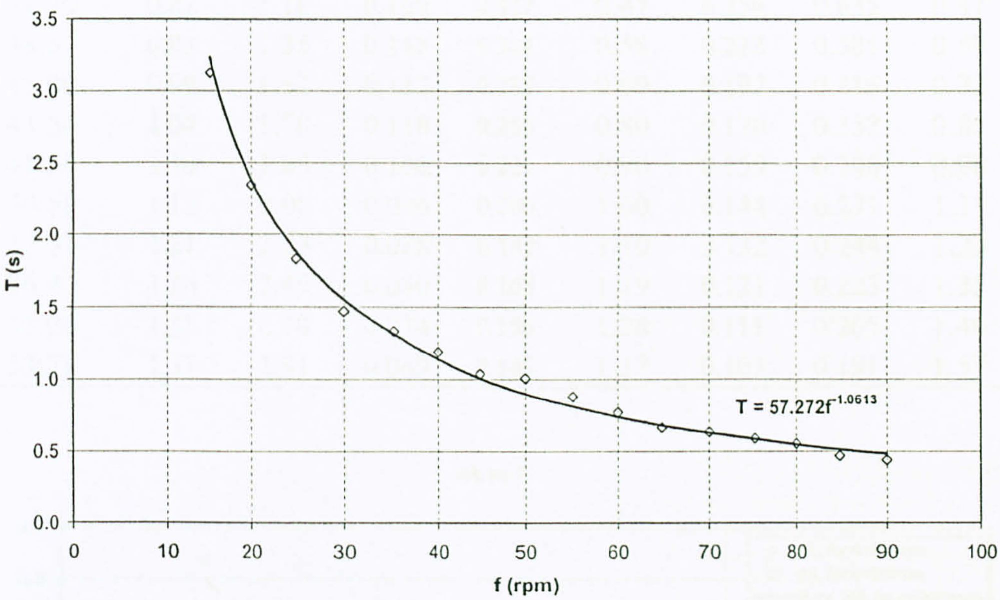


Figure 21: Plot of T versus f

4.3 DETERMINATION OF WATER CONDITION

The condition of water in terms of water depths used in this study were conducted to determine the performance of the floating breakwater models in specified classification of water depths i.e. deep water, transitional water and shallow water depths.

The wave periods used in the experiments are 0.87 sec, 0.93 sec, 0.99 sec, 1.04 sec, 1.10 sec, 1.15 sec, 1.21 sec, 1.26 sec, 1.31 sec and 1.37 sec. The wavelength, L_o in deep water condition is calculated using equation (2.9a).

The ratio of water depth, d to wavelength, L_o is then obtained. Using these values, with reference to the Table C-1 Shore Protection Manual (Appendix B), the value of *d/L* is obtained. From this, the length of wave at water depth 200 mm and 300 mm can be determined (see Table 8 and Appendix C).

Table 8: Wavelength at water depth of 200 mm and 300 mm

f (rpm)	T (s)	L_o (m)	d/L_o	d/L	L (m)	d/L_o	d/L	L (m)
			d = 200 mm			d = 300 mm		
55.33	0.81	1.02	0.196	0.558	0.36	0.293	0.836	0.36
51.70	0.87	1.18	0.169	0.427	0.47	0.254	0.635	0.47
48.51	0.93	1.35	0.148	0.344	0.58	0.222	0.505	0.59
45.90	0.99	1.52	0.132	0.289	0.69	0.197	0.416	0.72
43.54	1.04	1.70	0.118	0.250	0.80	0.176	0.352	0.85
41.50	1.10	1.88	0.106	0.221	0.90	0.159	0.306	0.98
39.59	1.15	2.08	0.096	0.200	1.00	0.144	0.271	1.11
37.91	1.21	2.28	0.088	0.182	1.10	0.132	0.244	1.23
36.40	1.26	2.49	0.080	0.168	1.19	0.121	0.223	1.35
35.03	1.31	2.70	0.074	0.156	1.28	0.111	0.205	1.46
33.78	1.37	2.91	0.069	0.146	1.37	0.103	0.191	1.57

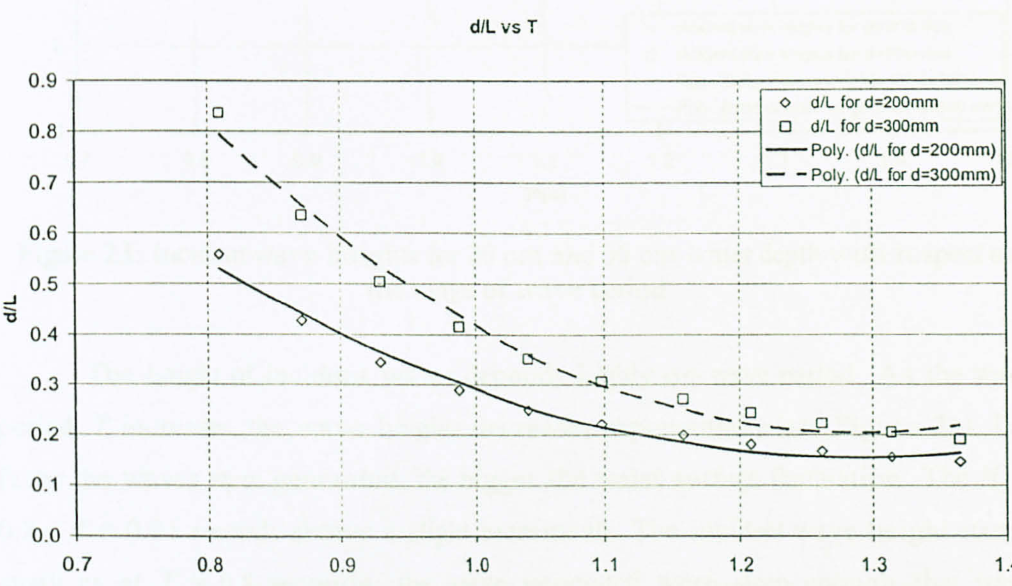


Figure 22: Classification of water condition

As wave period increases, the values of *d/L* decreases exponentially (see Figure 22). The experiments were conducted in transitional water as the *d/L* values are all in the range of 0.04 to 0.5.

4.4 DETERMINATION OF INCIDENT WAVE HEIGHT

In definition, incident wave height is the wave height approaching a structure at specific stroke frequency. The experiment was conducted without the floating breakwater models in the flume. This parameter of incident wave height, H_i is obtained to determine the coefficient of reflection, C_R and coefficient of transmission, C_T for water depth 200 mm and 300 mm at wave period ranging from 0.87 to 1.37 seconds.

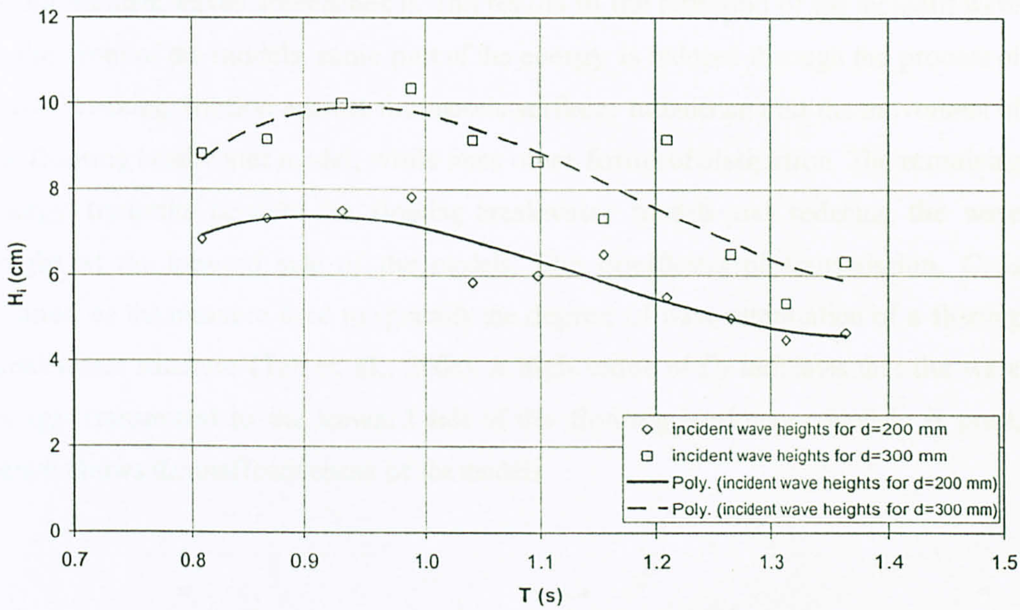


Figure 23: Incident wave heights for 20 cm and 30 cm water depth with respect to the range of wave period

The height of incident waves depends highly on wave period. As the wave period, T increases, the wave heights decreases exponentially (see Figure 23). The faster the waves were generated, the bigger the water surface fluctuation. The H_i at $0.8 < T < 0.95$ seconds shows a slight increments. The incident wave height started small as at T = 0.8 seconds, the wave generated were steep enough that wave breaking occurred. This cause most of the energy is loss through the breaking action. From T = 0.95 seconds onwards, H_i begin to decrease with the increase of wave period. The average H_i for water depth of 300 mm is greater compared to H_i for water depth of 200 mm.

4.5 THE GEOMETRY OF THE MODELS

The three models differ in term of the geometry. M1 is a box floating breakwater with vertical sides which acts as the control model, M2 has stepped sides, and M3 has a slopped sides (see Figure 24). The performance of the floating breakwater models were evaluated by comparing the transmitted wave heights, H_t with the incident wave heights, H_i.

A portion of the wave energy is reduced by the seaward surface of the models as the incident waves approaches it. This results in the reflection of the incident wave to the front of the models. some part of the energy is reduced through the process of wave breaking, friction against the models surface, turbulence and the movement of the floating breakwater model, while some other forms of dissipation. The remaining energy transmits beneath the floating breakwater models and reducing the wave height at the leeward side of the models. The coefficient of transmission, C_T is defined as the measure used to quantify the degree of wave attenuation of a floating breakwater structure (Teh et. al., 2006). A high value of C_T indicates that the wave energy transmitted to the leeward side of the floating breakwater models is great, hence shows the ineffectiveness of the models.

4.6 ANALYSIS OF RESULTS AND DISCUSSIONS

Twelve sets of experiments were conducted in order to determine the performance of the floating breakwater models. The models were tested in 20 cm and 30 cm water depths and anchored by pile and cable (see Figure 25). The analysis of the results focuses on the performance of the floating breakwater in transmitting waves. The heights of incident waves which were waves at the seaward side of the floating breakwater models and the heights of the transmitted waves which were waves at the leeward side of the models were recorded.

This section presents results obtained from the experiments conducted. Plots of the transmission coefficient, C_T versus three dimensionless parameters for both pile and cable system, are presented. The dimensionless parameters involved are H_i/D (15), $2\pi L/gT^2$ (16) and H_i/L (17). The calculations are summarized in Table 9.

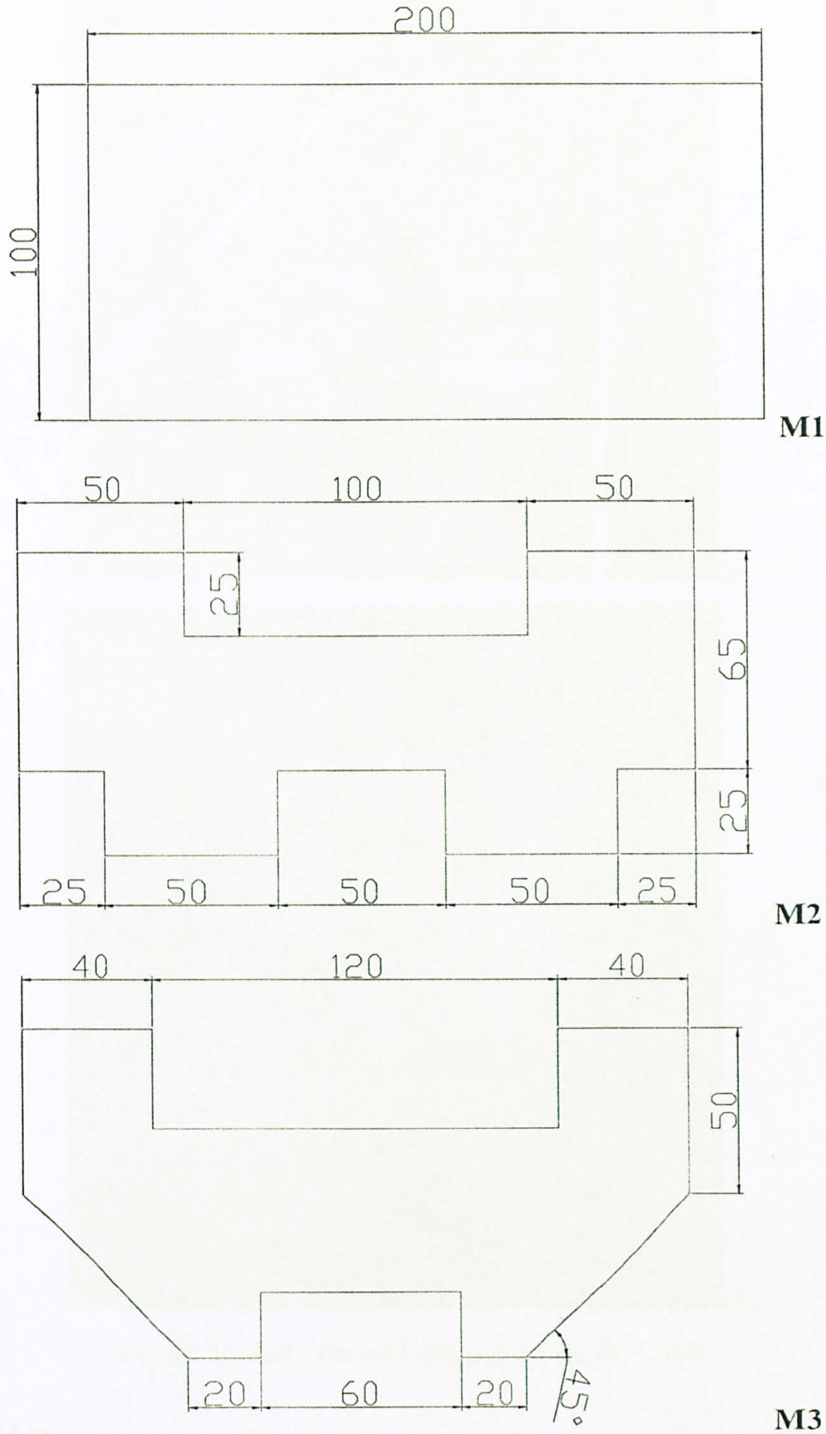
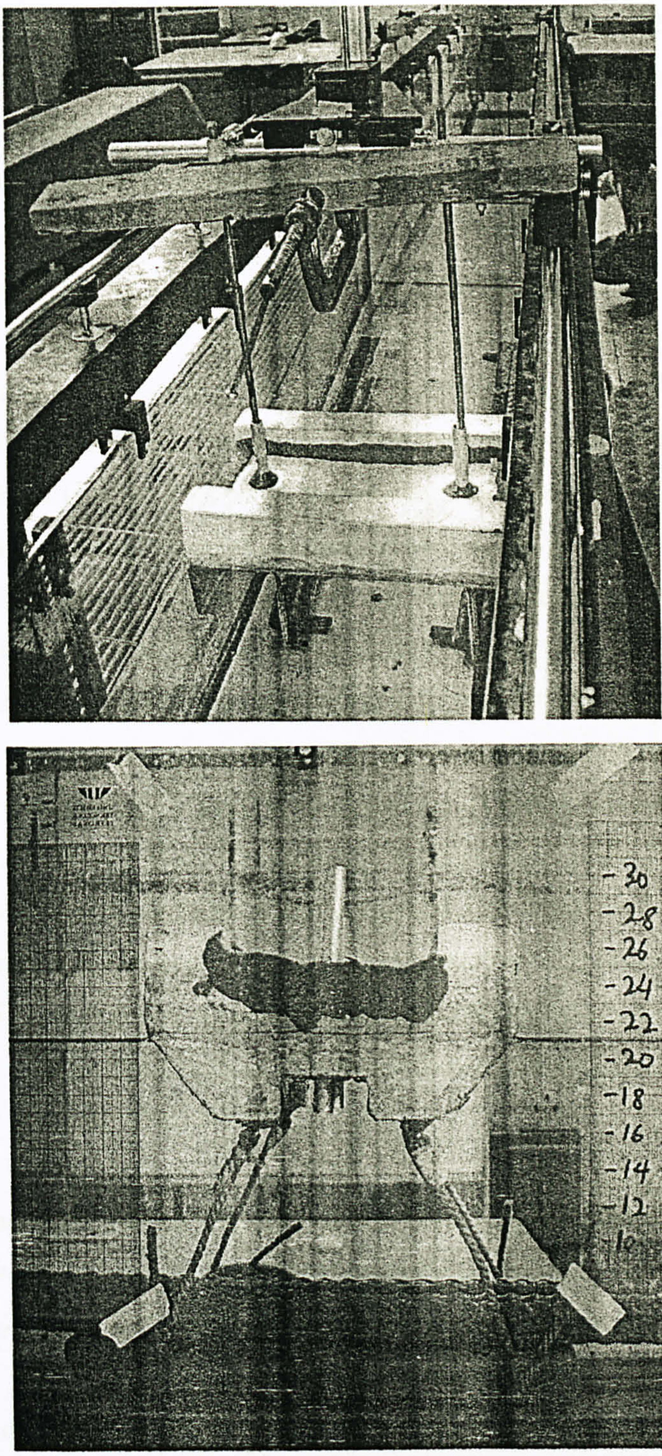


Figure 24: Section view of floating breakwater models (dimensions unit: mm)



(a)

(b)

Figure 25: Experimental setup (a) Pile, (b) Cable

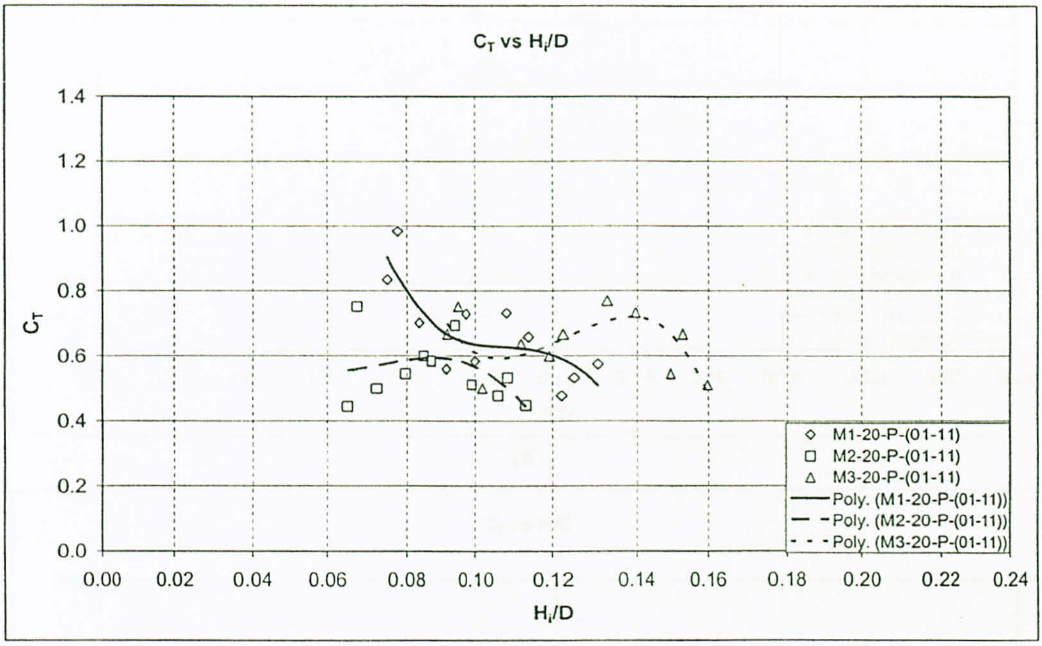
4.6.1 H_i/D

H_i is the incident wave height while D is the draft of the floating breakwater models. Plots in Figure 26 show the results for C_T versus H_i/D in water depths of 200 mm (see Figure 26 (a)) and 300 mm (see Figure 26 (b)). M1, M2 and M3 models were piled. This ratio relates the incident wave height for both water depths with the draft of each floating breakwater models to compare performance of each floating breakwater models with respect to the models' draft.

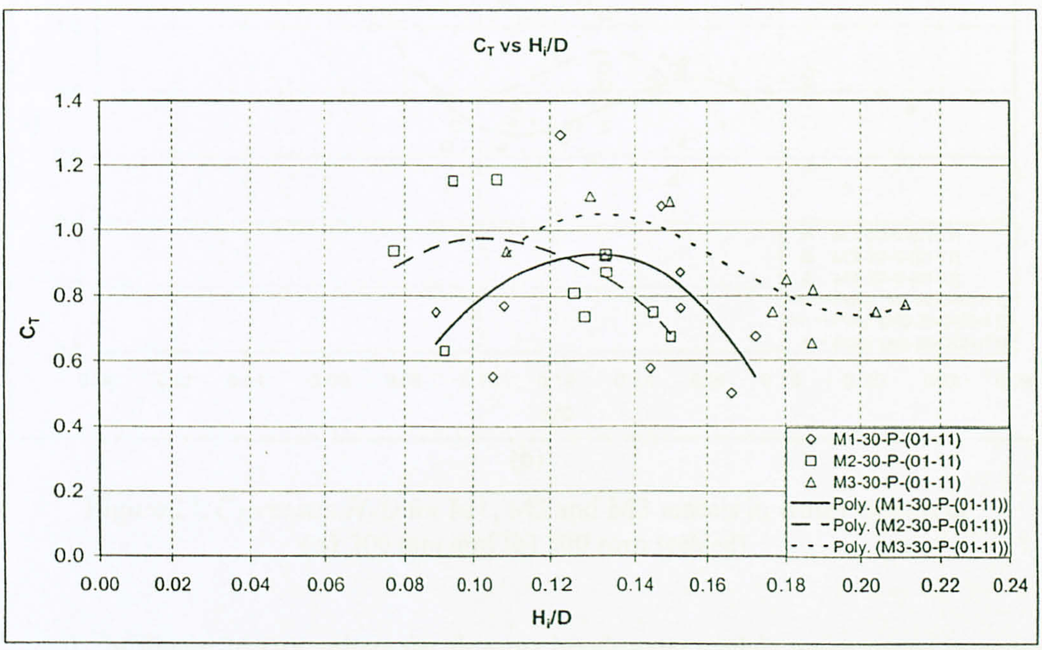
M1 has a draft of 60 mm, M2 has a draft of 69 mm and M3 has a draft of 49 mm. The results may be affected by the side surface of the models as all three models have different characteristics of its vertical side surfaces. From Figure 26 (a), the model with the vertical side, M1 has a higher level of C_T ranging from 0.9 to 0.6 at $0.075 < H_i/D < 0.115$. At this point, the incident wave height is close to 60 mm or more which is the same height of the draft of M1. After H_i/D of about 0.1, the value of C_T decrease slightly which shows that the performance of M1 increases as H_i/D increases which means that M1 performs better at higher wave period where incident wave heights are smaller. An intersection occurred at H_i/D of 0.115 where the performance of M1 increases while the performance of M3 decreases slightly. However, at point H_i/D is 0.140, the performance of the M3 model increases almost drastically. This shows that M3 performs its maximum when the incident wave height decreases (refer to Table 9 and Appendix D). While for M2, there were no obvious changes for C_T, but at H_i/D of approximately 0.09 when C_T is maximum (close to 0.6), the incident wave height obtained from the experiment is about 55 mm. M2 gives the lowest range for C_T while indicates that M2 performs best in water depth of 200 mm with draft of 69 mm.

As for Figure 26 (b), the models were tested against the same incident waves in water depth of 300 mm. A wide range of differences can be seen from the plots in Figure 25 (b). M1 and M2 creates a bell curve with maximum values for C_T of about 0.95 for M1 at H_i/D of roughly 0.1 and 0.93 for M2 at H_i/D of 0.13. M3 forms a polynomial curves with the maximum value for C_T of about 1.1 at H_i/D of 0.13. From this figure, M3 shows a better performance in attenuating waves.

Figures 27 shows the C_T versus H_i/D curves when the floating breakwater models were held in place by cables in 200 mm and 300 mm water depths. The values for C_T in both water depths were high which indicates that the performance of the floating breakwater models when using cable is low. Though so, in water depth of 200 mm (see Figure 27 (a)), M3 shows a convincing result in attenuating waves as C_T was about 0.6 at H_i/D of 0.12. After this point, the values of C_T increase only slightly at $0.12 < H_i/D < 0.16$.

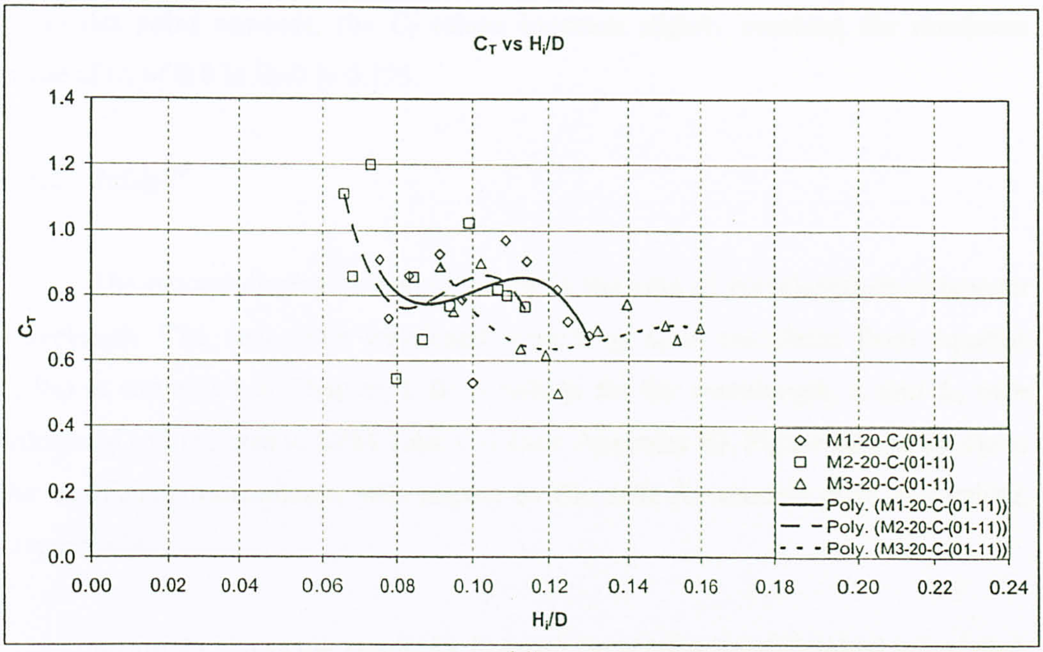


(a)

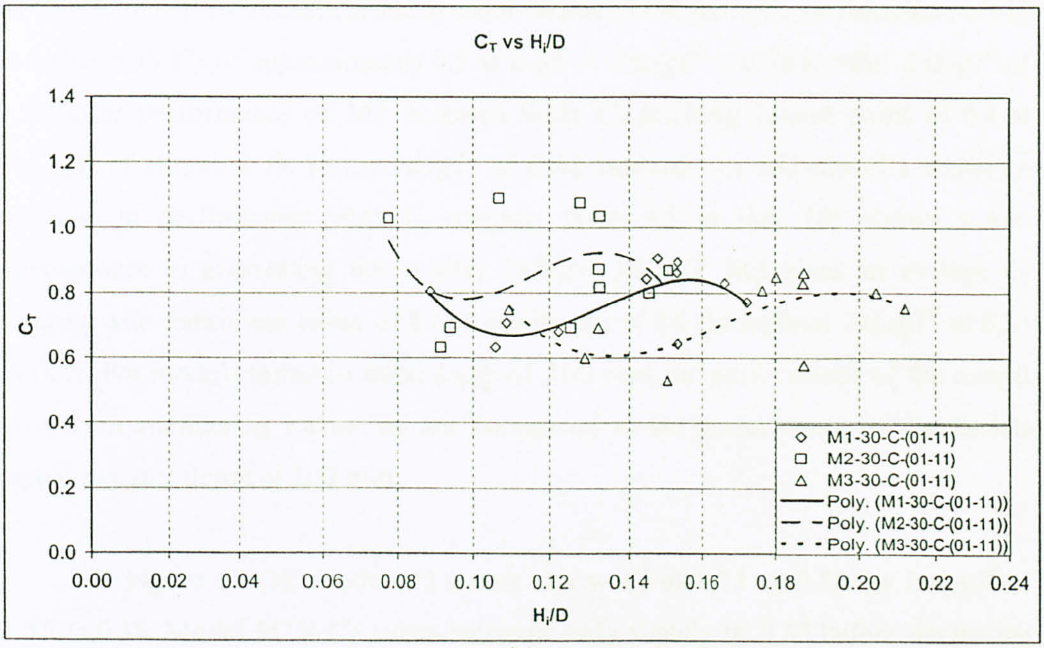


(b)

Figure 26: C_T versus H_i/D for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (piled)



(a)



(b)

Figure 27: C_T versus H_i/D for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (cabled)

In Figure 26 (b), where the floating breakwater models were tested in water depths of 300 mm, the values of C_T were lower. M3 still shows a convincing result in attenuating waves in water depth of 300 mm as C_T shows 0.6 at H_i/D of almost 0.14.

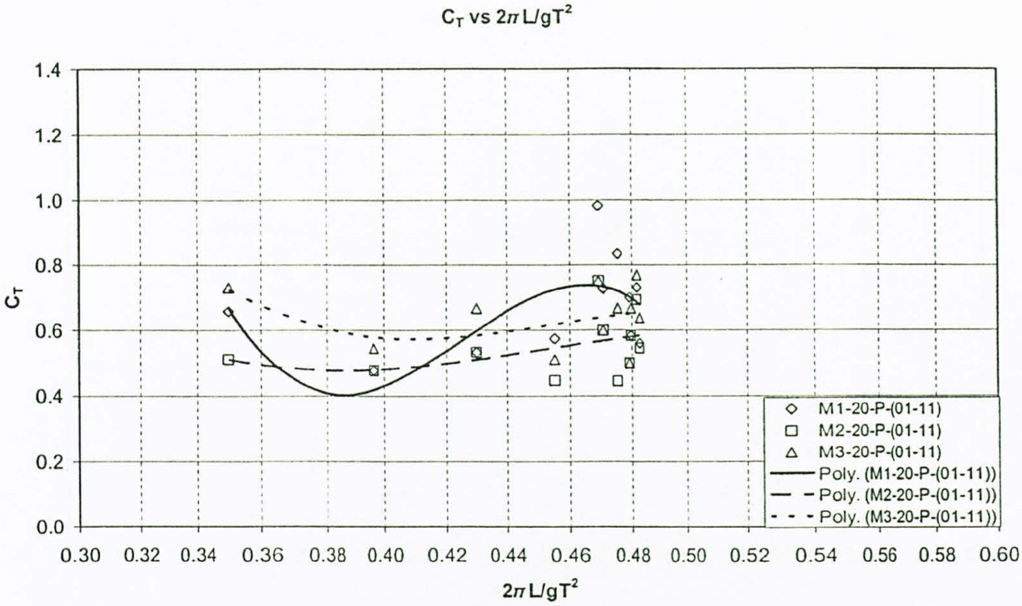
From this point onwards, the C_T values increase slightly reaching the maximum value of C_T of 0.8 at H_i/D is 0.195.

4.6.2 $2\pi L/gT^2$

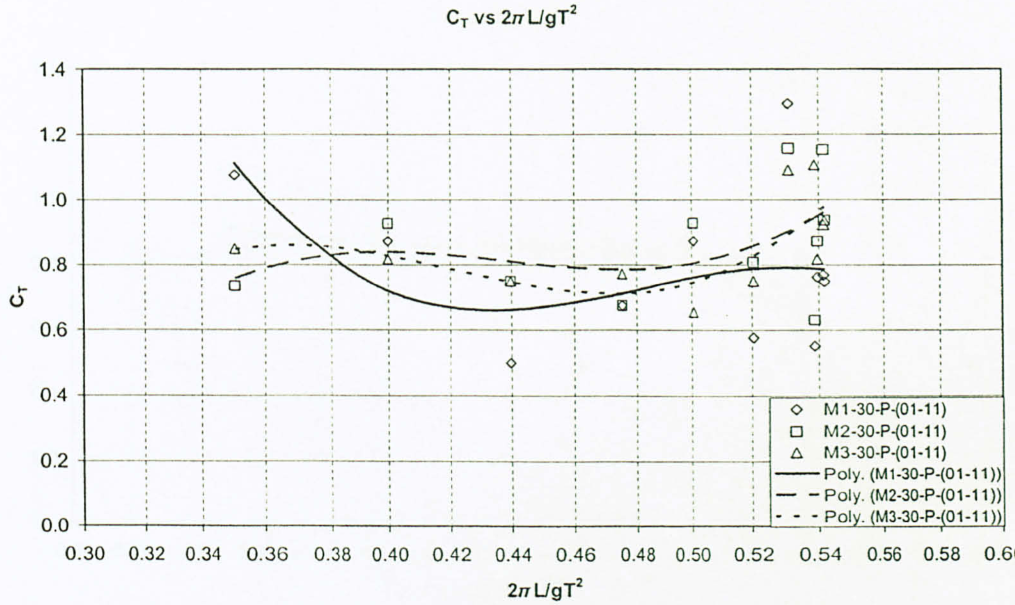
The second dimensionless parameter is the ratio of wavelength-to-deepwater wavelength. The deepwater wavelength noted by L_o is calculated from equation (2.9a) as explained in Chapter 2. Both values for the wavelength, L and L_o were calculated and referred to SPM Table C-1 (see Appendix B). Figure 28 and 29 shows the coefficient transmission with respect to the ratio for models piled and cabled, respectively.

Figure 28 shows the results for floating breakwater models tested when piled. In Figure 28 (a), for models tested in water depth of 200 mm, the performance of M2 is better with C_T of approximately 0.5 at $0.35 < 2\pi L/gT^2 < 0.365$. After $2\pi L/gT^2$ of 0.365, the performance of M1 increases with C_T reaching lowest point of 0.4 at $2\pi L/gT^2$ of almost 0.39. From $2\pi L/gT^2$ of 0.41 onwards the M2 model's shows an increase in performance with C_T ranging from 0.5 to 0.6. M1 shows a low performance in attenuating waves after $2\pi L/gT^2$ of 0.42. M3 gives an average C_T ranging with maximum value of 0.7 to minimum of 0.6 throughout $2\pi L/gT^2$ of 0.35 to 0.48. For models tested in water depth of 300 mm, the performance of the overall models in attenuating waves are low compared to the performance of the models tested in water depth of 200 mm.

In Figure 28 (b), model M2 shows a low C_T of 0.75 to 0.82 for $2\pi L/gT^2$ of 0.35 to 0.38. Model M2's C_T values increase only slightly to 0.83 before decreasing to just below 0.8 at $2\pi L/gT^2$ of 0.48 then increases almost linearly up to C_T of 0.95. Model M1 failed to attenuate waves when $2\pi L/gT^2$ of below 0.36. Beyond this point the C_T values for model M1 decreases drastically from over 1.0 to close to 0.6 at $2\pi L/gT^2$ of 0.43. The C_T values then increase almost insignificantly to 0.79 at $2\pi L/gT^2$ of nearly 0.52. The C_T values for M3 shows more or less the same values throughout the plots of $2\pi L/gT^2$ with C_T ranging from 0.85 to 0.7.



(a)



(b)

Figure 28: C_T versus $2\pi L/gT^2$ for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (piled)

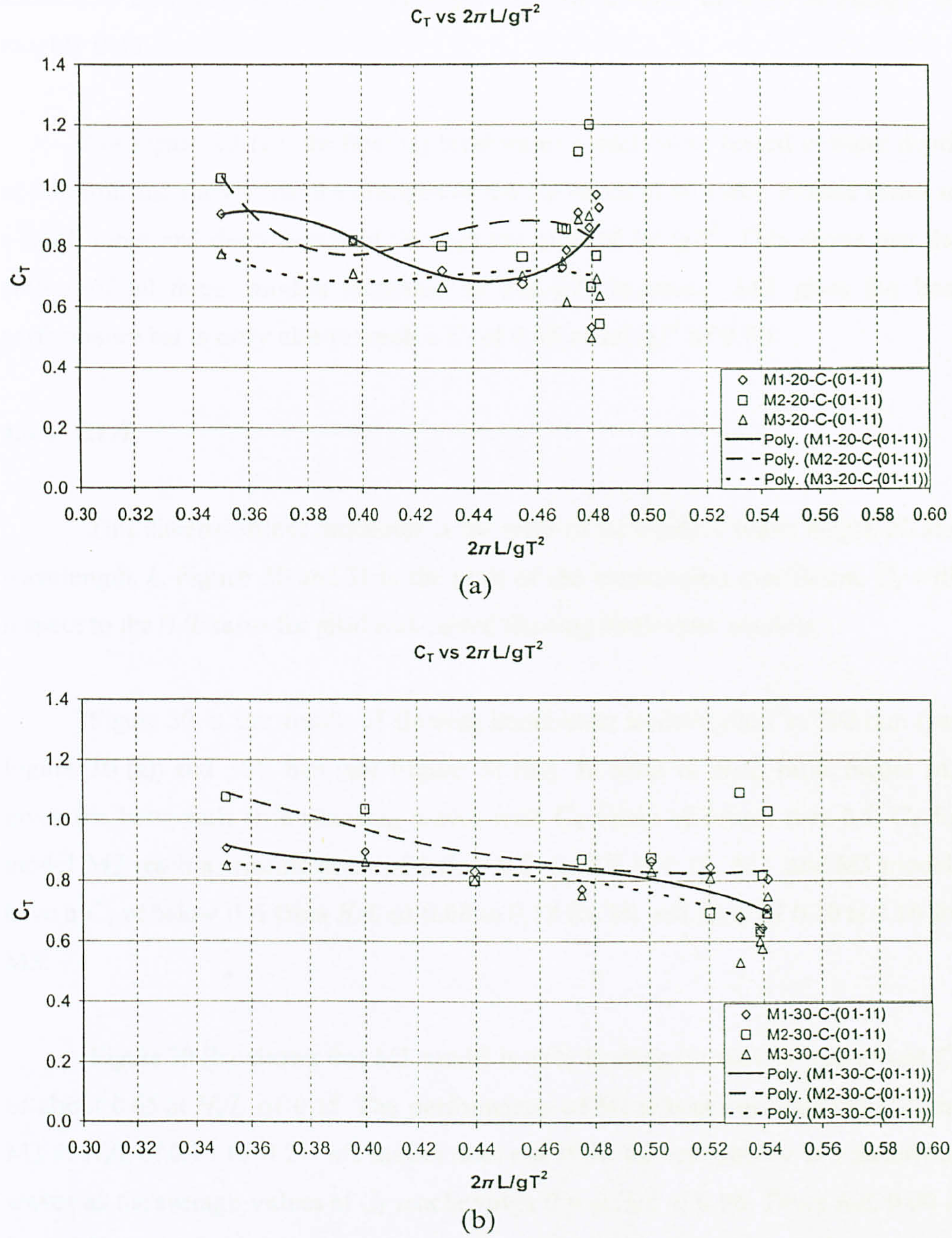


Figure 29: C_T versus $2\pi L/gT^2$ for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (cabled)

Figure 29 shows result for floating breakwater models when cabled. Figure 29 (a) is the result of models tested in 200 mm water depth which shows that model M3 having low values of C_T varies only slightly throughout the plots of $2\pi L/gT^2$ with maximum of 0.78 to minimum of 0.7. M1 and M2 models does not show a convincing performance in attenuating waves as the average C_T of the models were about 0.8. However, the C_T of M1 gives the lowest value of 0.69 at $2\pi L/gT^2$ of roughly 0.45.

For Figure 29 (b), the floating breakwater models were tested in water depth of 300 mm and shows that the changes of the C_T values of all three models varies in a small range and decreases right through the plots of $2\pi L/gT^2$. This shows that the ability of all three models increases as $2\pi L/gT^2$ increases. M3 gives the best performance but is only able to reach a C_T of 0.65 at $2\pi L/gT^2$ of 0.54.

4.6.3 H_i/L

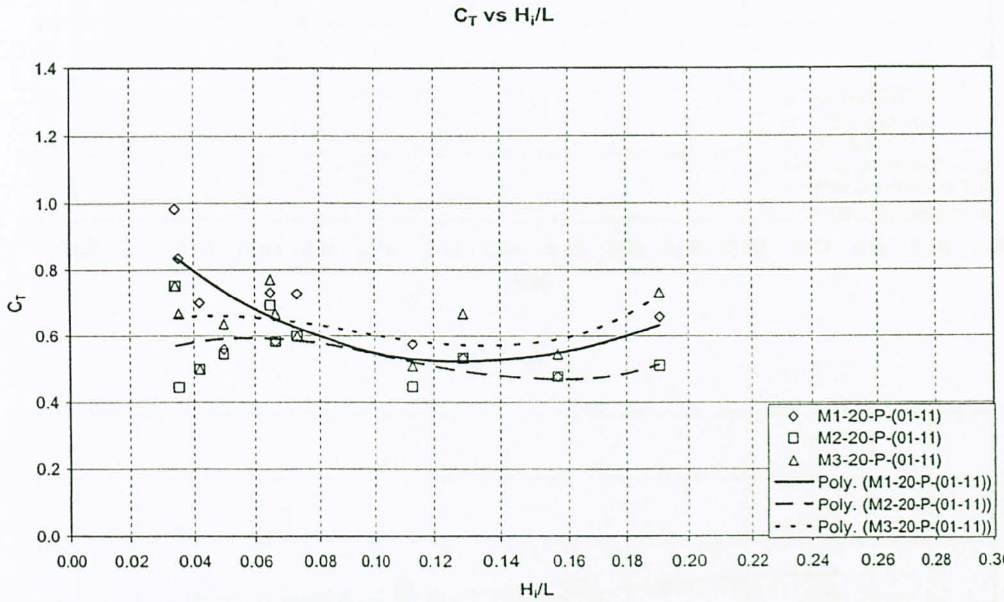
This dimensionless parameter is the ratio of the incident wave height, H_i and wavelength, L. Figure 30 and 31 is the plots of the transmission coefficient, C_T with respect to the H_i/L ratio for piled and cabled floating breakwater models.

Figure 30 is the results of floating breakwater models piled in 200 mm (see Figure 30 (a)) and 300 mm (see Figure 30 (b)). In terms of H_i/L ratio, model M2 gives the best result in attenuating waves with C_T values of lower then 0.6. C_T for model M2 reach a minimum C_T of below 0.5 at H_i/L of 0.16. M1 and M3 models have a C_T of below 0.6 from H_i/L of 0.08 to 0.18 for Ml and H_i/L of 0.10 to 0.16 for M3.

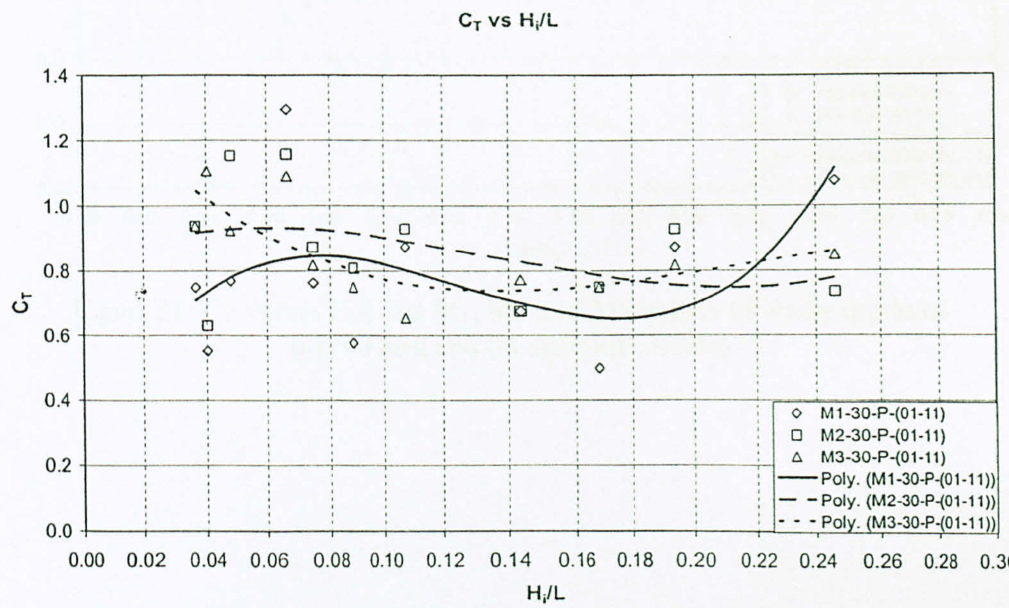
Figure 30 (b) shows that M1 model is able to attenuate waves with lowest C_T of about 0.65 at H_i/L of 0.18. The performance of Ml is best compared to M2 and M3 at H_i/L of 0.13 to 0.21. M2 model does not show the best ability in transmitting waves as the average values of C_T reaches over 0.9 at H_i/L of 0.06. From H_i/L 0.06 to 0.18, M2 model is unable to transmit more waves. Although so, the performance for M2 increases as the C_T is decreasing as H_i/L increases.

Figure 31 gives the results for floating breakwater models cabled. Figure 31 (a) shows result for floating breakwater models tested in 200 mm water depth. The overall performance of all three floating breakwater models are not so convincing as the lowest value of C_T is just slightly below 0.6 at H_i/L of 0.08, which is from M3 model. The range of C_T for M3 models is from 0.8 to 0.59 for H_i/L of 0.04 to 0.19.

The lowest C_T for M2 is around 0.7 at H_i/L of 0.09 while for M1 was 0.75 for H_i/L of 0.13. For models tested in 300 mm water depth, the overall C_T average was slightly above 0.8. The C_T values were increasing (see Figure 31 (b)) as H_i/L increases which means as the H_i/L ratio increase the performance of the floating breakwater models in attenuating waves decreases. M3 shows the most convincing result in transmitting waves for this plot.



(a)



(b)

Figure 30: C_T versus H_i/L for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (piled)

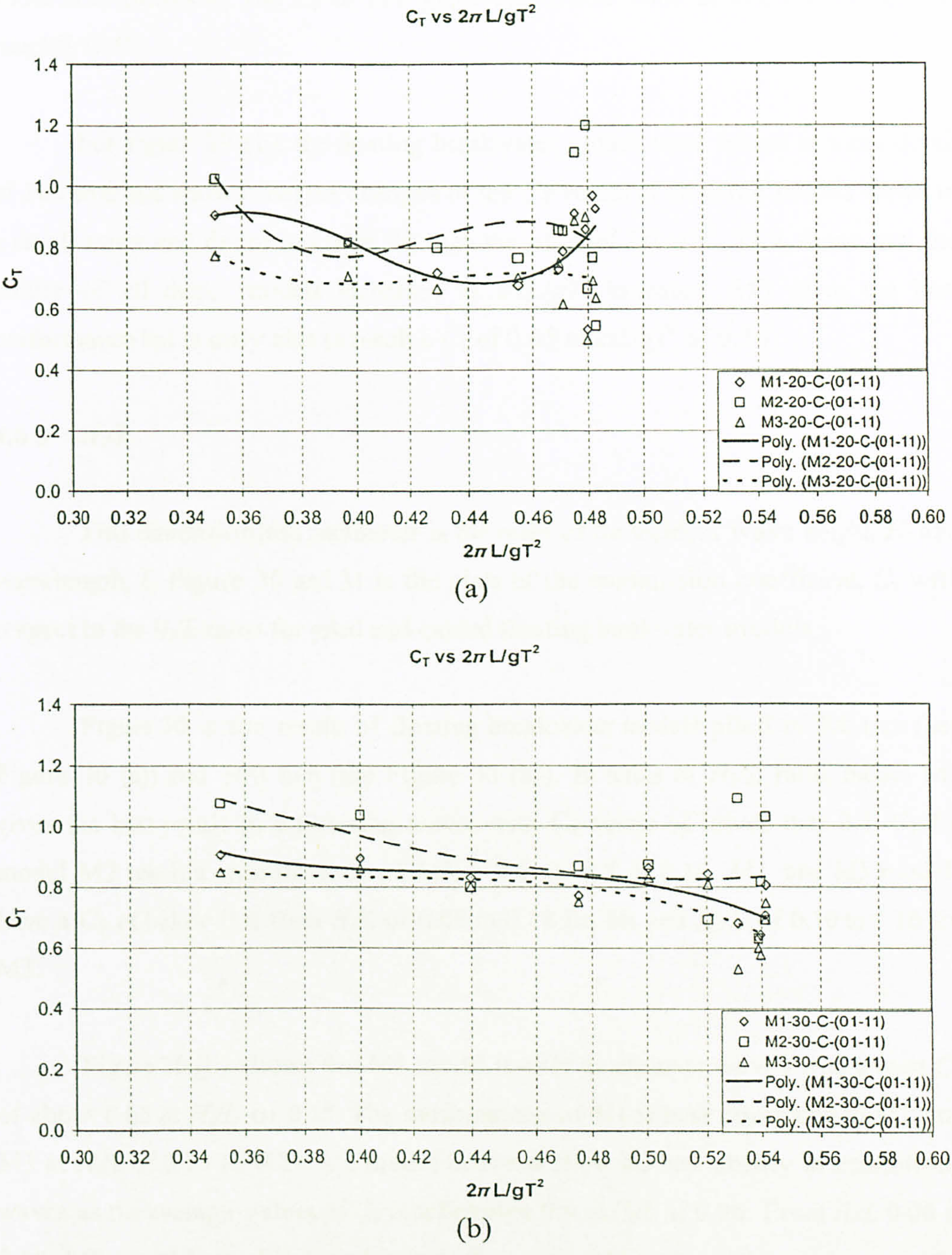


Figure 29: C_T versus $2\pi L/gT^2$ for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (cabled)

Figure 29 shows result for floating breakwater models when cabled. Figure 29 (a) is the result of models tested in 200 mm water depth which shows that model M3 having low values of C_T varies only slightly throughout the plots of $2\pi L/gT^2$ with maximum of 0.78 to minimum of 0.7. M1 and M2 models does not show a convincing performance in attenuating waves as the average C_T of the models were about 0.8. However, the C_T of M1 gives the lowest value of 0.69 at $2\pi L/gT^2$ of roughly 0.45.

For Figure 29 (b), the floating breakwater models were tested in water depth of 300 mm and shows that the changes of the C_T values of all three models varies in a small range and decreases right through the plots of $2\pi L/gT^2$. This shows that the ability of all three models increases as $2\pi L/gT^2$ increases. M3 gives the best performance but is only able to reach a C_T of 0.65 at $2\pi L/gT^2$ of 0.54.

4.6.3 H_i/L

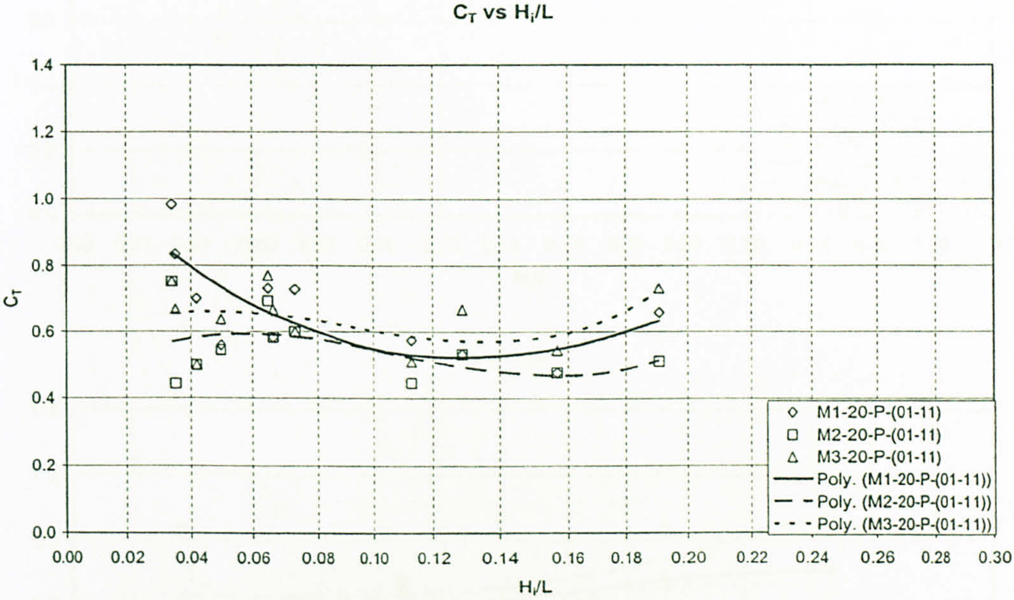
This dimensionless parameter is the ratio of the incident wave height, H_i and wavelength, L. Figure 30 and 31 is the plots of the transmission coefficient, C_T with respect to the H_i/L ratio for piled and cabled floating breakwater models.

Figure 30 is the results of floating breakwater models piled in 200 mm (see Figure 30 (a)) and 300 mm (see Figure 30 (b)). In terms of H_i/L ratio, model M2 gives the best result in attenuating waves with C_T values of lower then 0.6. C_T for model M2 reach a minimum C_T of below 0.5 at H_i/L of 0.16. M1 and M3 models have a C_T of below 0.6 from H_i/L of 0.08 to 0.18 for M1 and H_i/L of 0.10 to 0.16 for M3.

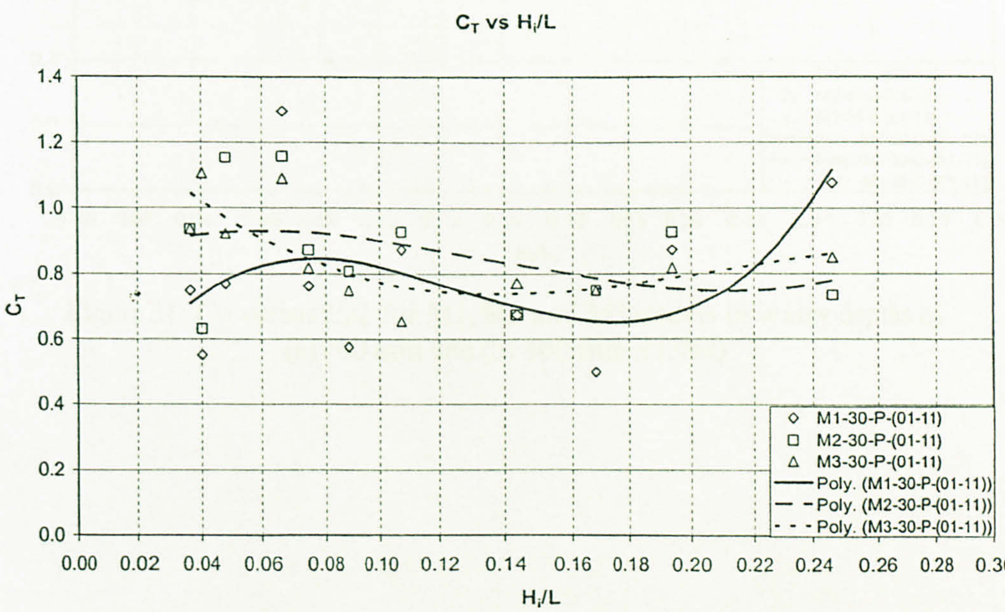
Figure 30 (b) shows that M1 model is able to attenuate waves with lowest C_T of about 0.65 at H_i/L of 0.18. The performance of M1 is best compared to M2 and M3 at H_i/L of 0.13 to 0.21. M2 model does not show the best ability in transmitting waves as the average values of C_T reaches over 0.9 at H_i/L of 0.06. From H_i/L 0.06 to 0.18, M2 model is unable to transmit more waves. Although so, the performance for M2 increases as the C_T is decreasing as H_i/L increases.

Figure 31 gives the results for floating breakwater models cabled. Figure 31 (a) shows result for floating breakwater models tested in 200 mm water depth. The overall performance of all three floating breakwater models are not so convincing as the lowest value of C_T is just slightly below 0.6 at H_i/L of 0.08, which is from M3 model. The range of C_T for M3 models is from 0.8 to 0.59 for H_i/L of 0.04 to 0.19.

The lowest C_T for M2 is around 0.7 at H_i/L of 0.09 while for M1 was 0.75 for H_i/L of 0.13. For models tested in 300 mm water depth, the overall C_T average was slightly above 0.8. The C_T values were increasing (see Figure 31 (b)) as H_i/L increases which means as the H_i/L ratio increase the performance of the floating breakwater models in attenuating waves decreases. M3 shows the most convincing result in transmitting waves for this plot.



(a)



(b)

Figure 30: C_T versus H_i/L for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (piled)

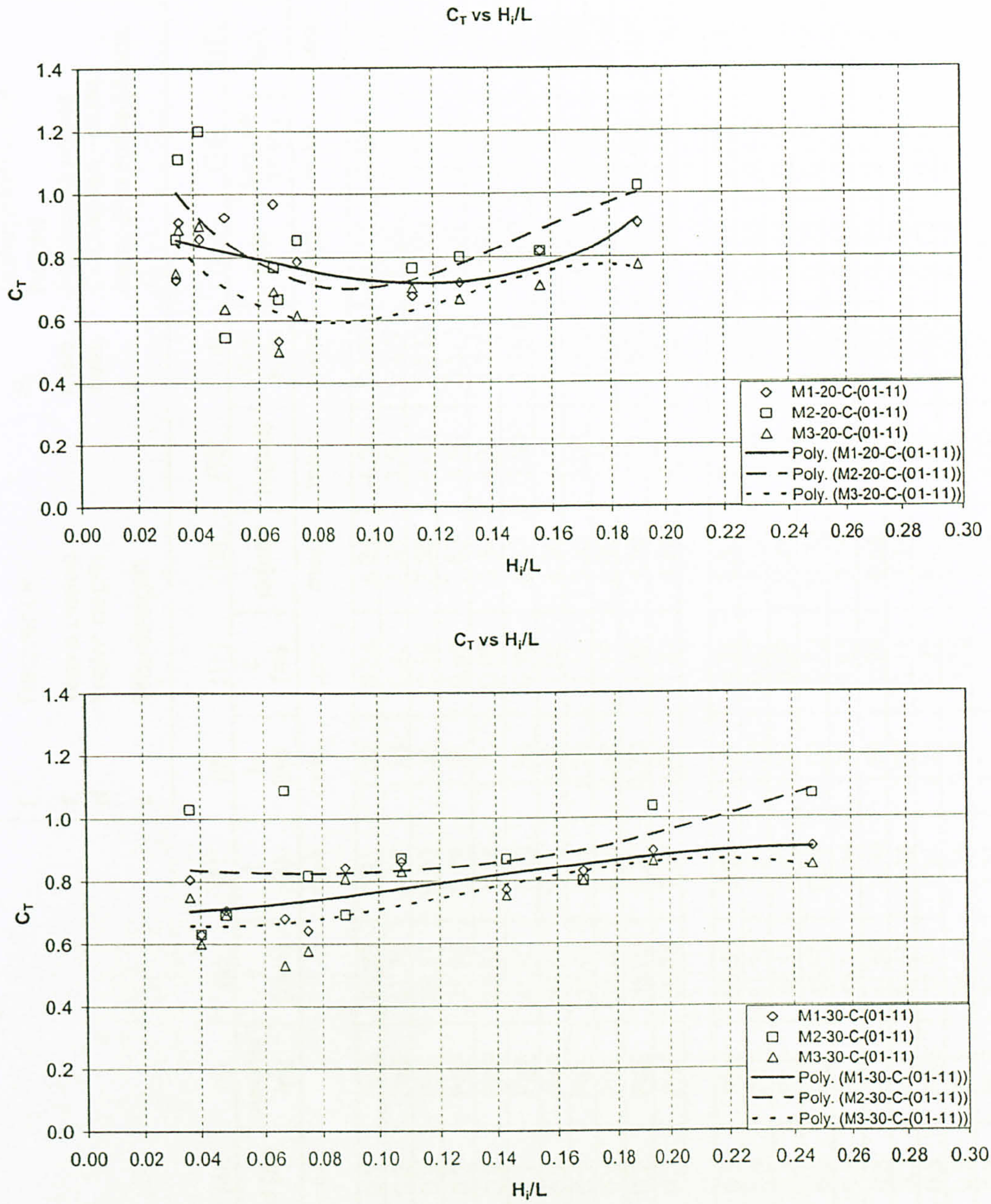


Figure 31: C_T versus H_i/L for M1, M2 and M3 models in water depths of (a) 200 mm and (b) 300 mm (cabled)

Table 9: Experiment set ups and results

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1) Experiments	(2) Model	(3) D (m)	(4) d (m)	(5) Anchoring	(6) f (rpm)	(7) T (s)	(8) L_o (m)	(11) L (m)	(12) H_i (cm)	(13) H_t (cm)	(14) $C_T = H_t/H_i$	(15) H_i/D	(16) $(2\pi L/gT^2) = L/L_o$	(17) H_i/L
		mea.	mea.			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M1-20-P-01	M1	0.60	0.2	PILE	55.33	0.81	1.02	0.36	6.84	4.50	0.658	0.114	0.350	0.191
M1-20-P-02		0.60	0.2	PILE	51.70	0.87	1.18	0.47	7.33	3.50	0.477	0.122	0.396	0.157
M1-20-P-03		0.60	0.2	PILE	48.51	0.93	1.35	0.58	7.50	4.00	0.533	0.125	0.430	0.129
M1-20-P-04		0.60	0.2	PILE	45.90	0.99	1.52	0.69	7.83	4.50	0.575	0.131	0.455	0.113
M1-20-P-05		0.60	0.2	PILE	43.54	1.04	1.70	0.80	5.84	4.25	0.728	0.097	0.470	0.073
M1-20-P-06		0.60	0.2	PILE	41.50	1.10	1.88	0.90	6.00	3.50	0.583	0.100	0.480	0.066
M1-20-P-07		0.60	0.2	PILE	39.59	1.15	2.08	1.00	6.50	4.75	0.731	0.108	0.482	0.065
M1-20-P-08		0.60	0.2	PILE	37.91	1.21	2.28	1.10	5.50	3.08	0.560	0.092	0.483	0.050
M1-20-P-09		0.60	0.2	PILE	36.40	1.26	2.49	1.19	5.00	3.50	0.700	0.083	0.479	0.042
M1-20-P-10		0.60	0.2	PILE	35.03	1.31	2.70	1.28	4.50	3.75	0.833	0.075	0.475	0.035
M1-20-P-11		0.60	0.2	PILE	33.78	1.37	2.91	1.37	4.66	4.58	0.983	0.078	0.469	0.034
M1-30-P-01	M1	0.60	0.3	PILE	55.33	0.81	1.02	0.36	8.83	9.50	1.076	0.147	0.351	0.246
M1-30-P-02		0.60	0.3	PILE	51.70	0.87	1.18	0.47	9.17	8.00	0.872	0.153	0.400	0.194
M1-30-P-03		0.60	0.3	PILE	48.51	0.93	1.35	0.59	10.00	5.00	0.500	0.167	0.440	0.168
M1-30-P-04		0.60	0.3	PILE	45.90	0.99	1.52	0.72	10.36	7.00	0.676	0.173	0.475	0.143
M1-30-P-05		0.60	0.3	PILE	43.54	1.04	1.70	0.85	9.16	8.00	0.873	0.153	0.501	0.108
M1-30-P-06		0.60	0.3	PILE	41.50	1.10	1.88	0.98	8.66	5.00	0.577	0.144	0.520	0.088
M1-30-P-07		0.60	0.3	PILE	39.59	1.15	2.08	1.11	7.34	9.50	1.294	0.122	0.531	0.066
M1-30-P-08		0.60	0.3	PILE	37.91	1.21	2.28	1.23	9.17	7.00	0.763	0.153	0.540	0.075
M1-30-P-09		0.60	0.3	PILE	36.40	1.26	2.49	1.35	6.50	5.00	0.769	0.108	0.541	0.048
M1-30-P-10		0.60	0.3	PILE	35.03	1.31	2.70	1.46	5.34	4.00	0.749	0.089	0.542	0.037
M1-30-P-11		0.60	0.3	PILE	33.78	1.37	2.91	1.57	6.33	3.50	0.553	0.106	0.539	0.040

Table 9: Experiment set ups and results (cont'd)

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Experiments	**Model**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$(2\pi L/gT^2) = L/L_o$**	**H_i/L**
		mea	mea			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M2-20-P-01	M2	0.69	0.2	PILE	55.33	0.81	1.02	0.36	6.84	3.50	0.5	0.10	0.35	0.19
M2-20-P-02		0.69	0.2	PILE	51.70	0.87	1.18	0.47	7.33	3.50	0.5	0.11	0.40	0.16
M2-20-P-03		0.69	0.2	PILE	48.51	0.93	1.35	0.58	7.50	4.00	0.5	0.11	0.43	0.13
M2-20-P-04		0.69	0.2	PILE	45.90	0.99	1.52	0.69	7.83	3.50	0.4	0.11	0.46	0.11
M2-20-P-05		0.69	0.2	PILE	43.54	1.04	1.70	0.80	5.84	3.50	0.6	0.08	0.47	0.07
M2-20-P-06		0.69	0.2	PILE	41.50	1.10	1.88	0.90	6.00	3.50	0.6	0.09	0.48	0.07
M2-20-P-07		0.69	0.2	PILE	39.59	1.15	2.08	1.00	6.50	4.50	0.7	0.09	0.48	0.06
M2-20-P-08		0.69	0.2	PILE	37.91	1.21	2.28	1.10	5.50	3.00	0.5	0.08	0.48	0.05
M2-20-P-09		0.69	0.2	PILE	36.40	1.26	2.49	1.19	5.00	2.50	0.5	0.07	0.48	0.04
M2-20-P-10		0.69	0.2	PILE	35.03	1.31	2.70	1.28	4.50	2.00	0.4	0.07	0.47	0.04
M2-20-P-11		0.69	0.2	PILE	33.78	1.37	2.91	1.37	4.66	3.50	0.8	0.07	0.47	0.03
M2-30-P-01	M2	0.69	0.3	PILE	55.33	0.81	1.02	0.36	8.83	6.50	0.7	0.13	0.35	0.25
M2-30-P-02		0.69	0.3	PILE	51.70	0.87	1.18	0.47	9.17	8.50	0.9	0.13	0.40	0.19
M2-30-P-03		0.69	0.3	PILE	48.51	0.93	1.35	0.59	10.00	7.50	0.8	0.14	0.44	0.17
M2-30-P-04		0.69	0.3	PILE	45.90	0.99	1.52	0.72	10.36	7.00	0.7	0.15	0.47	0.14
M2-30-P-05		0.69	0.3	PILE	43.54	1.04	1.70	0.85	9.16	8.50	0.9	0.13	0.50	0.11
M2-30-P-06		0.69	0.3	PILE	41.50	1.10	1.88	0.98	8.66	7.00	0.8	0.13	0.52	0.09
M2-30-P-07		0.69	0.3	PILE	39.59	1.15	2.08	1.11	7.34	8.50	1.2	0.11	0.53	0.07
M2-30-P-08		0.69	0.3	PILE	37.91	1.21	2.28	1.23	9.17	8.00	0.9	0.13	0.54	0.07
M2-30-P-09		0.69	0.3	PILE	36.40	1.26	2.49	1.35	6.50	7.50	1.2	0.09	0.54	0.05
M2-30-P-10		0.69	0.3	PILE	35.03	1.31	2.70	1.46	5.34	5.00	0.9	0.08	0.54	0.04
M2-30-P-11		0.69	0.3	PILE	33.78	1.37	2.91	1.57	6.33	4.00	0.6	0.09	0.54	0.04

Table 9: Experiment set ups and results (cont'd)

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1) Experiments	(2) Model	(3) D (m)	(4) d (m)	(5) Anchoring	(6) f (rpm)	(7) T (s)	(8) L_o (m)	(11) L (m)	(12) H_i (cm)	(13) H_t (cm)	(14) $C_T = H_t/H_i$	(15) H_i/D	(16) $(2\pi L/gT^2) = L/L_o$	(17) H_i/L
		mea	mea			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M3-20-P-01	M3	0.49	0.2	PILE	55.33	0.81	1.02	0.36	6.84	5.00	0.7	0.14	0.35	0.19
M3-20-P-02		0.49	0.2	PILE	51.70	0.87	1.18	0.47	7.33	4.00	0.5	0.15	0.40	0.16
M3-20-P-03		0.49	0.2	PILE	48.51	0.93	1.35	0.58	7.50	5.00	0.7	0.15	0.43	0.13
M3-20-P-04		0.49	0.2	PILE	45.90	0.99	1.52	0.69	7.83	4.00	0.5	0.16	0.46	0.11
M3-20-P-05		0.49	0.2	PILE	43.54	1.04	1.70	0.80	5.84	3.50	0.6	0.12	0.47	0.07
M3-20-P-06		0.49	0.2	PILE	41.50	1.10	1.88	0.90	6.00	4.00	0.7	0.12	0.48	0.07
M3-20-P-07		0.49	0.2	PILE	39.59	1.15	2.08	1.00	6.50	5.00	0.8	0.13	0.48	0.06
M3-20-P-08		0.49	0.2	PILE	37.91	1.21	2.28	1.10	5.50	3.50	0.6	0.11	0.48	0.05
M3-20-P-09		0.49	0.2	PILE	36.40	1.26	2.49	1.19	5.00	2.50	0.5	0.10	0.48	0.04
M3-20-P-10		0.49	0.2	PILE	35.03	1.31	2.70	1.28	4.50	3.00	0.7	0.09	0.47	0.04
M3-20-P-11		0.49	0.2	PILE	33.78	1.37	2.91	1.37	4.66	3.50	0.8	0.10	0.47	0.03
M3-30-P-01	M3	0.49	0.3	PILE	55.33	0.81	1.02	0.36	8.83	7.50	0.8	0.18	0.35	0.25
M3-30-P-02		0.49	0.3	PILE	51.70	0.87	1.18	0.47	9.17	7.50	0.8	0.19	0.40	0.19
M3-30-P-03		0.49	0.3	PILE	48.51	0.93	1.35	0.59	10.00	7.50	0.8	0.20	0.44	0.17
M3-30-P-04		0.49	0.3	PILE	45.90	0.99	1.52	0.72	10.36	8.00	0.8	0.21	0.47	0.14
M3-30-P-05		0.49	0.3	PILE	43.54	1.04	1.70	0.85	9.16	6.00	0.7	0.19	0.50	0.11
M3-30-P-06		0.49	0.3	PILE	41.50	1.10	1.88	0.98	8.66	6.50	0.8	0.18	0.52	0.09
M3-30-P-07		0.49	0.3	PILE	39.59	1.15	2.08	1.11	7.34	8.00	1.1	0.15	0.53	0.07
M3-30-P-08		0.49	0.3	PILE	37.91	1.21	2.28	1.23	9.17	7.50	0.8	0.19	0.54	0.07
M3-30-P-09		0.49	0.3	PILE	36.40	1.26	2.49	1.35	6.50	6.00	0.9	0.13	0.54	0.05
M3-30-P-10		0.49	0.3	PILE	35.03	1.31	2.70	1.46	5.34	5.00	0.9	0.11	0.54	0.04
M3-30-P-11		0.49	0.3	PILE	33.78	1.37	2.91	1.57	6.33	7.00	1.1	0.13	0.54	0.04

Table 9: Experiment set ups and results

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Experiments	**Model**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$(2\pi L/gT^2) = L/L_o$**	**H_i/L**
		mea.	mea.			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M1-20-C-01		0.60	0.2	CABLE	55.33	0.81	1.02	0.36	6.84	6.20	0.9	0.11	0.35	0.19
M1-20-C-02		0.60	0.2	CABLE	51.70	0.87	1.18	0.47	7.33	6.00	0.8	0.12	0.40	0.16
M1-20-C-03		0.60	0.2	CABLE	48.51	0.93	1.35	0.58	7.50	5.40	0.7	0.13	0.43	0.13
M1-20-C-04		0.60	0.2	CABLE	45.90	0.99	1.52	0.69	7.83	5.30	0.7	0.13	0.46	0.11
M1-20-C-05		0.60	0.2	CABLE	43.54	1.04	1.70	0.80	5.84	4.60	0.8	0.10	0.47	0.07
M1-20-C-06	M1	0.60	0.2	CABLE	41.50	1.10	1.88	0.90	6.00	3.20	0.5	0.10	0.48	0.07
M1-20-C-07		0.60	0.2	CABLE	39.59	1.15	2.08	1.00	6.50	6.30	1.0	0.11	0.48	0.06
M1-20-C-08		0.60	0.2	CABLE	37.91	1.21	2.28	1.10	5.50	5.10	0.9	0.09	0.48	0.05
M1-20-C-09		0.60	0.2	CABLE	36.40	1.26	2.49	1.19	5.00	4.30	0.9	0.08	0.48	0.04
M1-20-C-10		0.60	0.2	CABLE	35.03	1.31	2.70	1.28	4.50	4.10	0.9	0.08	0.47	0.04
M1-20-C-11		0.60	0.2	CABLE	33.78	1.37	2.91	1.37	4.66	3.40	0.7	0.08	0.47	0.03
M1-30-C-01		0.60	0.3	CABLE	55.33	0.81	1.02	0.36	8.83	8.00	0.9	0.15	0.35	0.25
M1-30-C-02		0.60	0.3	CABLE	51.70	0.87	1.18	0.47	9.17	8.20	0.9	0.15	0.40	0.19
M1-30-C-03		0.60	0.3	CABLE	48.51	0.93	1.35	0.59	10.00	8.30	0.8	0.17	0.44	0.17
M1-30-C-04		0.60	0.3	CABLE	45.90	0.99	1.52	0.72	10.36	8.00	0.8	0.17	0.47	0.14
M1-30-C-05		0.60	0.3	CABLE	43.54	1.04	1.70	0.85	9.16	7.90	0.9	0.15	0.50	0.11
M1-30-C-06	M1	0.60	0.3	CABLE	41.50	1.10	1.88	0.98	8.66	7.30	0.8	0.14	0.52	0.09
M1-30-C-07		0.60	0.3	CABLE	39.59	1.15	2.08	1.11	7.34	5.00	0.7	0.12	0.53	0.07
M1-30-C-08		0.60	0.3	CABLE	37.91	1.21	2.28	1.23	9.17	5.90	0.6	0.15	0.54	0.07
M1-30-C-09		0.60	0.3	CABLE	36.40	1.26	2.49	1.35	6.50	4.60	0.7	0.11	0.54	0.05
M1-30-C-10		0.60	0.3	CABLE	35.03	1.31	2.70	1.46	5.34	4.30	0.8	0.09	0.54	0.04
M1-30-C-11		0.60	0.3	CABLE	33.78	1.37	2.91	1.57	6.33	4.00	0.6	0.11	0.54	0.04

Table 9: Experiment set ups and results (cont'd)

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Experiments	**Model**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$(2\pi L/gT^2) = L/L_o$**	**H_i/L**
		mea	mea			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M2-20-C-01		0.69	0.2	CABLE	55.33	0.81	1.02	0.36	6.84	7.00	1.0	0.10	0.35	0.19
M2-20-C-02		0.69	0.2	CABLE	51.70	0.87	1.18	0.47	7.33	6.00	0.8	0.11	0.40	0.16
M2-20-C-03		0.69	0.2	CABLE	48.51	0.93	1.35	0.58	7.50	6.00	0.8	0.11	0.43	0.13
M2-20-C-04		0.69	0.2	CABLE	45.90	0.99	1.52	0.69	7.83	6.00	0.8	0.11	0.46	0.11
M2-20-C-05		0.69	0.2	CABLE	43.54	1.04	1.70	0.80	5.84	5.00	0.9	0.08	0.47	0.07
M2-20-C-06	M2	0.69	0.2	CABLE	41.50	1.10	1.88	0.90	6.00	4.00	0.7	0.09	0.48	0.07
M2-20-C-07		0.69	0.2	CABLE	39.59	1.15	2.08	1.00	6.50	5.00	0.8	0.09	0.48	0.06
M2-20-C-08		0.69	0.2	CABLE	37.91	1.21	2.28	1.10	5.50	3.00	0.5	0.08	0.48	0.05
M2-20-C-09		0.69	0.2	CABLE	36.40	1.26	2.49	1.19	5.00	6.00	1.2	0.07	0.48	0.04
M2-20-C-10		0.69	0.2	CABLE	35.03	1.31	2.70	1.28	4.50	5.00	1.1	0.07	0.47	0.04
M2-20-C-11		0.69	0.2	CABLE	33.78	1.37	2.91	1.37	4.66	4.00	0.9	0.07	0.47	0.03
M2-30-C-01		0.69	0.3	CABLE	55.33	0.81	1.02	0.36	8.83	9.50	1.1	0.13	0.35	0.25
M2-30-C-02		0.69	0.3	CABLE	51.70	0.87	1.18	0.47	9.17	9.50	1.0	0.13	0.40	0.19
M2-30-C-03		0.69	0.3	CABLE	48.51	0.93	1.35	0.59	10.00	8.00	0.8	0.14	0.44	0.17
M2-30-C-04		0.69	0.3	CABLE	45.90	0.99	1.52	0.72	10.36	9.00	0.9	0.15	0.47	0.14
M2-30-C-05		0.69	0.3	CABLE	43.54	1.04	1.70	0.85	9.16	8.00	0.9	0.13	0.50	0.11
M2-30-C-06	M2	0.69	0.3	CABLE	41.50	1.10	1.88	0.98	8.66	6.00	0.7	0.13	0.52	0.09
M2-30-C-07		0.69	0.3	CABLE	39.59	1.15	2.08	1.11	7.34	8.00	1.1	0.11	0.53	0.07
M2-30-C-08		0.69	0.3	CABLE	37.91	1.21	2.28	1.23	9.17	7.50	0.8	0.13	0.54	0.07
M2-30-C-09		0.69	0.3	CABLE	36.40	1.26	2.49	1.35	6.50	4.50	0.7	0.09	0.54	0.05
M2-30-C-10		0.69	0.3	CABLE	35.03	1.31	2.70	1.46	5.34	5.50	1.0	0.08	0.54	0.04
M2-30-C-11		0.69	0.3	CABLE	33.78	1.37	2.91	1.57	6.33	4.00	0.6	0.09	0.54	0.04

Table 9: Experiment set ups and results (cont'd)

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1) Experiments	(2) Model	(3) D (m)	(4) d (m)	(5) Anchoring	(6) f (rpm)	(7) T (s)	(8) L_o (m)	(11) L (m)	(12) H_i (cm)	(13) H_t (cm)	(14) $C_T = H_t/H_i$	(15) H_i/D	(16) $(2\pi L/gT^2) = L/L_o$	(17) H_i/L
		mea	mea			mea.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.
M3-20-C-01		0.49	0.2	CABLE	55.33	0.81	1.02	0.36	6.84	5.30	0.8	0.14	0.35	0.19
M3-20-C-02		0.49	0.2	CABLE	51.70	0.87	1.18	0.47	7.33	5.20	0.7	0.15	0.40	0.16
M3-20-C-03		0.49	0.2	CABLE	48.51	0.93	1.35	0.58	7.50	5.00	0.7	0.15	0.43	0.13
M3-20-C-04		0.49	0.2	CABLE	45.90	0.99	1.52	0.69	7.83	5.50	0.7	0.16	0.46	0.11
M3-20-C-05		0.49	0.2	CABLE	43.54	1.04	1.70	0.80	5.84	3.60	0.6	0.12	0.47	0.07
M3-20-C-06	M3	0.49	0.2	CABLE	41.50	1.10	1.88	0.90	6.00	3.00	0.5	0.12	0.48	0.07
M3-20-C-07		0.49	0.2	CABLE	39.59	1.15	2.08	1.00	6.50	4.50	0.7	0.13	0.48	0.06
M3-20-C-08		0.49	0.2	CABLE	37.91	1.21	2.28	1.10	5.50	3.50	0.6	0.11	0.48	0.05
M3-20-C-09		0.49	0.2	CABLE	36.40	1.26	2.49	1.19	5.00	4.50	0.9	0.10	0.48	0.04
M3-20-C-10		0.49	0.2	CABLE	35.03	1.31	2.70	1.28	4.50	4.00	0.9	0.09	0.47	0.04
M3-20-C-11		0.49	0.2	CABLE	33.78	1.37	2.91	1.37	4.66	3.50	0.8	0.10	0.47	0.03
M3-30-C-01		0.49	0.3	CABLE	55.33	0.81	1.02	0.36	8.83	7.50	0.8	0.18	0.35	0.25
M3-30-C-02		0.49	0.3	CABLE	51.70	0.87	1.18	0.47	9.17	7.90	0.9	0.19	0.40	0.19
M3-30-C-03		0.49	0.3	CABLE	48.51	0.93	1.35	0.59	10.00	8.00	0.8	0.20	0.44	0.17
M3-30-C-04		0.49	0.3	CABLE	45.90	0.99	1.52	0.72	10.36	7.80	0.8	0.21	0.47	0.14
M3-30-C-05		0.49	0.3	CABLE	43.54	1.04	1.70	0.85	9.16	7.60	0.8	0.19	0.50	0.11
M3-30-C-06	M3	0.49	0.3	CABLE	41.50	1.10	1.88	0.98	8.66	7.00	0.8	0.18	0.52	0.09
M3-30-C-07		0.49	0.3	CABLE	39.59	1.15	2.08	1.11	7.34	3.90	0.5	0.15	0.53	0.07
M3-30-C-08		0.49	0.3	CABLE	37.91	1.21	2.28	1.23	9.17	5.30	0.6	0.19	0.54	0.07
M3-30-C-09		0.49	0.3	CABLE	36.40	1.26	2.49	1.35	6.50	4.50	0.7	0.13	0.54	0.05
M3-30-C-10		0.49	0.3	CABLE	35.03	1.31	2.70	1.46	5.34	4.00	0.7	0.11	0.54	0.04
M3-30-C-11		0.49	0.3	CABLE	33.78	1.37	2.91	1.57	6.33	3.80	0.6	0.13	0.54	0.04

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The series of experiments and analysed results has proven the wave attenuation ability of the floating breakwater models. A number of conclusions have been made at the end of this study.

From the results discussed it is seen that floating breakwater model M2 shows a convincing result in transmitting waves. By comparing all three models performance using the coefficient of transmission with respect to the three dimensionless parameters, M3 model gives the lowest C_T value.

For H_i/D ratio, M3 model shows the best ability in transmitting waves in 200 mm and 300 mm water depths anchored by cables. In water depth 200 mm, piled models, M2 model shows a better result while M1 models shows the best ability in 300 mm when piled. For $2\pi L/gT^2$ and H_i/L ratios, M3 model shows the best ability in transmitting waves in 300 mm when piled, and 200 mm and 300 mm when anchored by cables. In water depth of 200 mm, M2 model shows a better performance when piled.

With reference to the table of the summary results in Appendix D, the average C_T for each category of experiments are as in Table 15. The results shows that experiment M2-20-P-(01-11) gives the lowest average of C_T. This indicates that the performance of M2 model is most effective when in shallow water depth condition and fixed in place by piles. M2 model is able to transmit almost 50 percent of the incident wave height compared to M1 and M3 models. For the overall performance of each model in various conditions, M1 model shows the best performance when in shallow water condition, piled but transmit only about 30 percent of the incident wave height. On the other hand, M3 model shows its effectiveness when in transitional water condition, piled, where almost 40 percent of the incident wave height is transmitted.

It can also be conclude that the floating breakwater models appear to perform more effectively when piled as there were minimum movement horizontally. This increases the ability of the floating breakwater model to reflect the energy of waves, hence, transmits lesser energy to the leeward side of the models.

As conclusion, the most effective floating breakwater model is M2 model which is the duplicate model of WSS.

Table 100: Average C_T for each category of experiment

Category of Experiment	C_T average
M1-20-P-(01-11)	0.699
M1-30-P-(01-11)	0.791
M2-20-P-(01-11)	0.553
M2-30-P-(01-11)	0.871
M3-20-P-(01-11)	0.640
M3-30-P-(01-11)	0.861
M1-20-C-(01-11)	0.804
M1-30-C-(01-11)	0.780
M2-20-C-(01-11)	0.856
M2-30-C-(01-11)	0.874
M3-20-C-(01-11)	0.713
M3-30-C-(01-11)	0.732

5.2 RECOMMENDATION

Improvement could be made on the study of the WSS. The followings are a few recommendations.

1. More study could be conducted with various drafts. Previous studies have proven that the increase in draft could increase the attenuation ability of a floating structure.

2. Additional experiments should be conducted to evaluate the performance of the WSS in deep water. Improvements could be made to increase the ability of the WSS to attenuate waves in deep water. This may lead to a larger market as floating breakwaters are more preferable at coastal protection in deep water conditions.
3. Future experiments could also be conducted with a wider range of wave periods. The performance of the models in long wave period conditions can be evaluated and studied.
4. Various arrangements of mooring systems for the models anchoring system should be conducted to identify the affects of the arrangements to the attenuation ability of the floating breakwaters.

REFERENCES

Dean, R.G. and Dalrymple, R.A. (1991) *Water wave mechanics for engineers and Scientists*, Advanced Series on Ocean Engineering, Vol. 2, World Scientific, Singapore.

Fousert, M. W. (2006). *Floating Breakwater: Theoretical Study of a Dynamic Wave Attenuating System.*

McCartney, B. L. (1985) *Floating Breakwater Design, Journal to Waterway, Port, Coastal and Ocean Engineering.* Vol III. ASCE. pp.307-317.

National Coastal Erosion Study, Nov 1984 – Jan 1986 by the Malaysian Government (http://www.water.gov.my/index.php?option=com_content&task=view&id=30&Itemid=184)

Reeve D., Chadwick A., Fleming C. (2004) Coasting Engineering. *Processes, theory and design practice,* 1st ed., London and New York: Spon Press.

Sorensen, R.M. (1993) *Basic Wave Mechanics for Coastal and Ocean Engineers*, 2nd ed., New York: John Wiley & Sons.

Teh, H. M., Nuruddin, M. F., Hisham, M. F. (2007). *Experimental Study on the Wave Attenuation Performance of a Floating Breakwater.* Universiti Teknologi PETRONAS, Tronoh.

Central Intelligence Agency, CIA. (March 2008) THE WORLD FACTBOOK <https://www.cia.gov/library/publications/the-world-factbook/index.html>

APPENDIX A

SUMMARY OF SMALL AMPLITUDE / LINEAR (AIRY) WAVE THEORY

RELATIVE DEPTH	SHALLOW WATER $\frac{d}{L} < \frac{1}{25}$	TRANSITIONAL WATER $\frac{1}{25} < \frac{d}{L} < \frac{1}{2}$	DEEP WATER $\frac{d}{L} > \frac{1}{2}$
1. Wave profile	Same As $\longrightarrow$	$\eta = \frac{H}{2} \cos\left[\frac{2\pi x}{L} - \frac{2\pi t}{T}\right] = \frac{H}{2}\cos\theta$	Same As $\longleftarrow$
2. Wave celerity	$C = \frac{L}{T} = \sqrt{gd}$	$C = \frac{L}{T} = \frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$C = C_o = \frac{L}{T} = \frac{gT}{2\pi}$
3. Wavelength	$L = T\sqrt{gd} = CT$	$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$L = L_o = \frac{gT^2}{2\pi} = C_oT$
4. Group velocity	$C_g = C = \sqrt{gd}$	$C_g = nC = \frac{1}{2}\left[1 + \frac{4\pi d/L}{\sinh(4\pi d/L)}\right]\cdot C$	$C_g = \frac{1}{2}C = \frac{gT}{4\pi}$
5. Water Particle Velocity (a) Horizontal	$u = \frac{H}{2}\sqrt{\frac{g}{d}}\cos\theta$	$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$u = \frac{\pi H}{T} e^{\frac{2\pi z}{L}} \cos\theta$
(b) Vertical	$w = \frac{H\pi}{T}\left(1 + \frac{z}{d}\right)\sin\theta$	$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$w = \frac{\pi H}{T} e^{\frac{2\pi z}{L}} \sin\theta$
6. Water Particle Accelerations (a) Horizontal	$a_x = \frac{H\pi}{T}\sqrt{\frac{g}{d}}\sin\theta$	$a_x = \frac{g\pi H}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$a_x = 2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}} \sin\theta$
(b) Vertical	$a_z = -2H\left(\frac{\pi}{T}\right)^2\left(1 + \frac{z}{d}\right)\cos\theta$	$a_z = -\frac{g\pi H}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$a_z = -2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}} \cos\theta$
7. Water Particle Displacements (a) Horizontal	$\xi = -\frac{HT}{4\pi}\sqrt{\frac{g}{d}}\sin\theta$	$\xi = -\frac{H}{2}\frac{\cosh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\sin\theta$	$\xi = -\frac{H}{2} e^{\frac{2\pi z}{L}} \sin\theta$
(b) Vertical	$\zeta = \frac{H}{2}\left(1 + \frac{z}{d}\right)\cos\theta$	$\zeta = \frac{H}{2}\frac{\sinh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\cos\theta$	$\zeta = \frac{H}{2} e^{\frac{2\pi z}{L}} \cos\theta$
8. Subsurface Pressure	$p = \rho g(\eta - z)$	$p = \rho g\eta\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)} - \rho gz$	$p = \rho g\eta e^{\frac{2\pi z}{L}} - \rho gz$

Summary of Small Amplitude/ Linear (Airy) Wave Theory Expressions

APPENDIX B

TABLE C-1: SPM TABLE

FUNCTIONS OF d/L FOR EVEN INCREMENTS OF d/L_O

Table C-1. Functions of d/L for even increments of d/L_o (from 0.0001 to 1.000).

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$ *	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H_o'	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
0	0	0	0	0	1	∞	1	0	0	1	1	0	∞
.000100	.003990	.02507	.02506	.02507	1.0003	4.467	.9997	.05014	.05016	1.001	.9998	.02506	7,855
.000200	.005643	.03546	.03544	.03547	1.0006	3.757	.9994	.07091	.07097	1.003	.9996	.03543	3,928
.000300	.006912	.04343	.04340	.04344	1.0009	3.395	.9991	.08686	.08697	1.004	.9994	.04336	2,620
.000400	.007982	.05015	.05011	.05018	1.0013	3.160	.9987	.1003	.1005	1.005	.9992	.05007	1,965
.000500	.008925	.05608	.05602	.05611	1.0016	2.989	.9984	.1122	.1124	1.006	.9990	.05596	1,572
.000600	.009778	.06144	.06136	.06148	1.0019	2.856	.9981	.1229	.1232	1.008	.9988	.06128	1,311
.000700	.01056	.06637	.06627	.06642	1.0022	2.749	.9978	.1327	.1331	1.009	.9985	.06617	1,124
.000800	.01129	.07096	.07084	.07102	1.0025	2.659	.9975	.1419	.1424	1.010	.9983	.07072	983.5
.000900	.01198	.07527	.07513	.07534	1.0028	2.582	.9972	.1505	.1511	1.011	.9981	.07499	874.3
.001000	.01263	.07935	.07918	.07943	1.0032	2.515	.9969	.1587	.1594	1.013	.9979	.07902	787.0
.001100	.01325	.08323	.08304	.08333	1.0035	2.456	.9966	.1665	.1672	1.014	.9977	.08285	715.6
.001200	.01384	.08694	.08672	.08705	1.0038	2.404	.9962	.1739	.1748	1.015	.9975	.08651	656.1
.001300	.01440	.09050	.09026	.09063	1.0041	2.357	.9959	.1810	.1820	1.016	.9973	.09001	605.8
.001400	.01495	.09393	.09365	.09407	1.0044	2.314	.9956	.1879	.1890	1.018	.9971	.09338	562.6
.001500	.01548	.09723	.09693	.09739	1.0047	2.275	.9953	.1945	.1957	1.019	.9969	.09663	525
.001600	.01598	.1004	.1001	.1006	1.0051	2.239	.9949	.2009	.2022	1.020	.9967	.09977	493
.001700	.01648	.1035	.1032	.1037	1.0054	2.205	.9946	.2071	.2086	1.022	.9965	.1028	463
.001800	.01696	.1066	.1062	.1068	1.0057	2.174	.9943	.2131	.2147	1.023	.9962	.1058	438
.001900	.01743	.1095	.1091	.1097	1.0060	2.145	.9940	.2190	.2207	1.024	.9960	.1087	415
.002000	.01788	.1123	.1119	.1125	1.0063	2.119	.9937	.2247	.2266	1.025	.9958	.1114	394
.002100	.01832	.1151	.1146	.1154	1.0066	2.094	.9934	.2303	.2323	1.027	.9956	.1141	376
.002200	.01876	.1178	.1173	.1181	1.0069	2.070	.9931	.2357	.2379	1.028	.9954	.1161	359
.002300	.01918	.1205	.1199	.1208	1.0073	2.047	.9928	.2410	.2433	1.029	.9952	.1193	343
.002400	.01959	.1231	.1225	.1234	1.0076	2.025	.9925	.2462	.2487	1.031	.9950	.1219	329
.002500	.02000	.1257	.1250	.1260	1.0079	2.005	.9922	.2513	.2540	1.032	.9948	.1243	316
.002600	.02040	.1282	.1275	.1285	1.0082	1.986	.9919	.2563	.2592	1.033	.9946	.1268	304
.002700	.02079	.1306	.1299	.1310	1.0085	1.967	.9916	.2612	.2642	1.034	.9944	.1292	292
.002800	.02117	.1330	.1323	.1334	1.0089	1.950	.9912	.2661	.2692	1.036	.9942	.1315	282
.002900	.02155	.1354	.1346	.1358	1.0092	1.933	.9909	.2708	.2741	1.037	.9939	.1338	272
.003000	.02192	.1377	.1369	.1382	1.0095	1.917	.9906	.2755	.2790	1.038	.9937	.1360	263
.003100	.02228	.1400	.1391	.1405	1.0098	1.902	.9903	.2800	.2837	1.040	.9935	.1382	255
.003200	.02264	.1423	.1413	.1427	1.0101	1.887	.9900	.2845	.2884	1.041	.9933	.1404	247
.003300	.02300	.1445	.1435	.1449	1.0104	1.873	.9897	.2890	.2930	1.042	.9931	.1425	240
.003400	.02335	.1467	.1456	.1472	1.0108	1.860	.9893	.2934	.2976	1.043	.9929	.1446	233
.003500	.02369	.1488	.1477	.1494	1.0111	1.847	.9890	.2977	.3021	1.045	.9927	.1466	226
.003600	.02403	.1510	.1498	.1515	1.0114	1.834	.9887	.3020	.3065	1.046	.9925	.1487	220
.003700	.02436	.1531	.1519	.1537	1.0117	1.822	.9884	.3061	.3109	1.047	.9923	.1507	214
.003800	.02469	.1551	.1539	.1558	1.0121	1.810	.9881	.3103	.3153	1.049	.9921	.1527	208
.003900	.02502	.1572	.1559	.1579	1.0124	1.799	.9878	.3144	.3196	1.050	.9919	.1546	203
.004000	.02534	.1592	.1579	.1599	1.0127	1.788	.9875	.3184	.3238	1.051	.9917	.1565	198
.004100	.02566	.1612	.1598	.1619	1.0130	1.777	.9872	.3224	.3280	1.052	.9915	.1584	193
.004200	.02597	.1632	.1617	.1639	1.0133	1.767	.9869	.3263	.3322	1.054	.9912	.1602	189
.004300	.02628	.1651	.1636	.1659	1.0137	1.756	.9865	.3302	.3362	1.055	.9910	.1621	184
.004400	.02659	.1671	.1655	.1678	1.0140	1.746	.9862	.3341	.3403	1.056	.9908	.1640	180
.004500	.02689	.1690	.1674	.1698	1.0143	1.737	.9859	.3380	.3444	1.058	.9906	.1658	176
.004600	.02719	.1708	.1692	.1717	1.0146	1.727	.9856	.3417	.3483	1.059	.9904	.1676	172
.004700	.02749	.1727	.1710	.1736	1.0149	1.718	.9853	.3454	.3523	1.060	.9902	.1693	169
.004800	.02778	.1745	.1728	.1754	1.0153	1.709	.9849	.3491	.3562	1.062	.9900	.1711	165
.004900	.02807	.1764	.1746	.1773	1.0156	1.701	.9846	.3527	.3601	1.063	.9898	.1728	162
.005000	.02836	.1782	.1764	.1791	1.0159	1.692	.9843	.3564	.3640	1.064	.9896	.1746	159
.005100	.02864	.1800	.1781	.1809	1.0162	1.684	.9840	.3599	.3678	1.066	.9894	.1762	156
.005200	.02893	.1818	.1798	.1827	1.0166	1.676	.9837	.3635	.3715	1.067	.9892	.1779	153
.005300	.02921	.1835	.1815	.1845	1.0169	1.669	.9834	.3670	.3753	1.068	.9889	.1795	150
.005400	.02948	.1852	.1832	.1863	1.0172	1.662	.9831	.3705	.3790	1.069	.9887	.1811	147
.005500	.02976	.1870	.1848	.1880	1.0175	1.654	.9828	.3739	.3827	1.071	.9885	.1827	145
.005500	.03003	.1887	.1865	.1898	1.0178	1.647	.9825	.3774	.3864	1.072	.9883	.1843	142
.005700	.03030	.1904	.1881	.1915	1.0182	1.640	.9822	.3808	.3900	1.073	.9881	.1859	140
.005800	.03057	.1921	.1897	.1932	1.0185	1.633	.9818	.3841	.3937	1.075	.9879	.1874	137
.005900	.03083	.1937	.1913	.1949	1.0188	1.626	.9815	.3875	.3972	1.076	.9877	.1890	135

*Also: b_s/a_s, C/C_o, L/L_c

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.006000	.03110	.1954	.1929	.1967	1.0192	1.620	.9812	.3908	.4008	1.077	.9875	.1905	133
.006100	.03136	.1970	.1945	.1983	1.0195	1.614	.9809	.3941	.4044	1.079	.9873	.1920	130
.006200	.03162	.1987	.1961	.2000	1.0198	1.607	.9806	.3973	.4079	1.080	.9871	.1935	128
.006300	.03188	.2003	.1976	.2016	1.0201	1.601	.9803	.4006	.4114	1.081	.9869	.1950	126
.006400	.03213	.2019	.1992	.2033	1.0205	1.595	.9799	.4038	.4148	1.083	.9867	.1965	124
.006500	.03238	.2035	.2007	.2049	1.0208	1.589	.9796	.4070	.4183	1.084	.9865	.1980	123
.006600	.03264	.2051	.2022	.2065	1.0211	1.583	.9793	.4101	.4217	1.085	.9863	.1994	121
.006700	.03289	.2066	.2037	.2081	1.0214	1.578	.9790	.4133	.4251	1.087	.9860	.2009	119
.006800	.03313	.2082	.2052	.2097	1.0217	1.572	.9787	.4164	.4285	1.088	.9858	.2023	117
.006900	.03338	.2097	.2067	.2113	1.0221	1.567	.9784	.4195	.4319	1.089	.9856	.2037	116
.007000	.03362	.2113	.2082	.2128	1.0224	1.561	.9781	.4225	.4352	1.091	.9854	.2051	114
.007100	.03387	.2128	.2096	.2144	1.0227	1.556	.9778	.4256	.4386	1.092	.9852	.2065	112
.007200	.03411	.2143	.2111	.2160	1.0231	1.551	.9774	.4286	.4419	1.093	.9850	.2079	111
.007300	.03435	.2158	.2125	.2175	1.0234	1.546	.9771	.4316	.4452	1.095	.9848	.2093	109
.007400	.03459	.2173	.2139	.2190	1.0237	1.541	.9768	.4346	.4484	1.096	.9846	.2106	108
.007500	.03482	.2188	.2154	.2205	1.0240	1.536	.9765	.4376	.4517	1.097	.9844	.2120	106
.007600	.03506	.2203	.2168	.2221	1.0244	1.531	.9762	.4406	.4549	1.099	.9842	.2134	105
.007700	.03529	.2218	.2182	.2236	1.0247	1.526	.9759	.4435	.4582	1.100	.9840	.2147	104
.007800	.03552	.2232	.2196	.2251	1.0250	1.521	.9756	.4464	.4614	1.101	.9838	.2160	102
.007900	.03576	.2247	.2209	.2265	1.0253	1.517	.9753	.4493	.4646	1.103	.9836	.2173	101
.008000	.03598	.2261	.2223	.2280	1.0257	1.512	.9750	.4522	.4678	1.104	.9834	.2186	100
.008100	.03621	.2275	.2237	.2295	1.0260	1.508	.9747	.4551	.4709	1.105	.9832	.2199	98.6
.008200	.03644	.2290	.2250	.2310	1.0263	1.503	.9744	.4579	.4741	1.107	.9830	.2212	97.5
.008300	.03666	.2304	.2264	.2324	1.0266	1.499	.9741	.4607	.4772	1.108	.9827	.2225	96.3
.008400	.03689	.2318	.2277	.2338	1.0270	1.495	.9737	.4636	.4803	1.109	.9825	.2237	95.2
.008500	.03711	.2332	.2290	.2353	1.0273	1.491	.9734	.4664	.4834	1.111	.9823	.2250	94.1
.008600	.03733	.2346	.2303	.2367	1.0276	1.487	.9731	.4691	.4865	1.112	.9821	.2262	93.0
.008700	.03755	.2360	.2317	.2381	1.0280	1.482	.9728	.4719	.4896	1.113	.9819	.2275	91.9
.008800	.03777	.2373	.2330	.2396	1.0283	1.478	.9725	.4747	.4927	1.115	.9817	.2287	90.9
.008900	.03799	.2387	.2343	.2410	1.0286	1.474	.9722	.4774	.4957	1.116	.9815	.2300	89.9
.009000	.03821	.2401	.2356	.2424	1.0290	1.471	.9718	.4801	.4988	1.118	.9813	.2312	88.9
.009100	.03842	.2414	.2368	.2438	1.0293	1.467	.9715	.4828	.5018	1.119	.9811	.2324	88.0
.009200	.03864	.2428	.2381	.2452	1.0296	1.463	.9712	.4855	.5049	1.120	.9809	.2336	87.1
.009300	.03885	.2441	.2394	.2465	1.0299	1.459	.9709	.4882	.5079	1.122	.9807	.2348	86.1
.009400	.03906	.2455	.2407	.2479	1.0303	1.456	.9706	.4909	.5109	1.123	.9805	.2360	85.2
.009500	.03928	.2468	.2419	.2493	1.0306	1.452	.9703	.4936	.5138	1.124	.9803	.2371	84.3
.009600	.03949	.2481	.2431	.2507	1.0309	1.448	.9700	.4962	.5168	1.126	.9801	.2383	83.5
.009700	.03970	.2494	.2443	.2520	1.0313	1.445	.9697	.4988	.5198	1.127	.9799	.2394	82.7
.009800	.03990	.2507	.2456	.2534	1.0316	1.442	.9694	.5014	.5227	1.128	.9797	.2406	81.8
.009900	.04011	.2520	.2468	.2547	1.0319	1.438	.9691	.5040	.5257	1.130	.9794	.2417	81.0
.01000	.04032	.2533	.2480	.2560	1.0322	1.435	.9688	.5066	.5286	1.131	.9792	.2429	80.2
.01100	.04233	.2660	.2598	.2691	1.0356	1.403	.9656	.5319	.5574	1.145	.9772	.2539	73.1
.01200	.04426	.2781	.2711	.2817	1.0389	1.375	.9625	.5562	.5853	1.159	.9751	.2643	67.1
.01300	.04612	.2898	.2820	.2938	1.0423	1.350	.9594	.5795	.6125	1.173	.9731	.2743	62.1
.01400	.04791	.3010	.2924	.3056	1.0456	1.327	.9564	.6020	.6391	1.187	.9710	.2838	57.8
.01500	.04964	.3119	.3022	.3170	1.0490	1.307	.9533	.6238	.6651	1.201	.9690	.2928	54.0
.01600	.05132	.3225	.3117	.3281	1.0524	1.288	.9502	.6450	.6906	1.215	.9670	.3014	50.8
.01700	.05296	.3328	.3209	.3389	1.0559	1.271	.9471	.6655	.7158	1.230	.9649	.3096	47.9
.01800	.05455	.3428	.3298	.3495	1.0593	1.255	.9440	.6856	.7405	1.244	.9629	.3176	45.3
.01900	.05611	.3525	.3386	.3599	1.0628	1.240	.9409	.7051	.7650	1.259	.9609	.3253	43.0
.02000	.05763	.3621	.3470	.3701	1.0663	1.226	.9378	.7242	.7891	1.274	.9588	.3327	41.0
.02100	.05912	.3714	.3552	.3800	1.0698	1.213	.9348	.7429	.8131	1.289	.9568	.3399	39.1
.02200	.06057	.3806	.3632	.3898	1.0733	1.201	.9317	.7612	.8368	1.304	.9548	.3468	37.4
.02300	.06200	.3896	.3710	.3995	1.0768	1.189	.9287	.7791	.8603	1.319	.9528	.3535	35.9
.02400	.06340	.3984	.3786	.4090	1.0804	1.178	.9256	.7967	.8837	1.335	.9508	.3600	34.4
.02500	.06478	.4070	.3860	.4184	1.0840	1.168	.9225	.8140	.9069	1.350	.9488	.3662	33.1
.02600	.06613	.4155	.3932	.4276	1.0876	1.159	.9195	.8310	.9310	1.366	.9468	.3722	31.9
.02700	.06747	.4239	.4002	.4367	1.0912	1.150	.9164	.8478	.9530	1.381	.9448	.3781	30.8
.02800	.06878	.4322	.4071	.4457	1.0949	1.141	.9133	.8643	.9760	1.397	.9428	.3838	29.8
.02900	.07007	.4403	.4138	.4546	1.0985	1.133	.9103	.8805	.9988	1.413	.9408	.3893	28.8

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H_o'	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.03000	.07135	.4483	.4205	.4634	1.1021	1.125	.9073	.8966	1.022	1.430	.9388	.3947	27.9
.03100	.07260	.4562	.4269	.4721	1.1059	1.118	.9042	.9124	1.044	1.446	.9369	.4000	27.1
.03200	.07385	.4640	.4333	.4808	1.1096	1.111	.9012	.9280	1.067	1.462	.9349	.4051	26.3
.03300	.07507	.4717	.4395	.4894	1.1133	1.104	.8982	.9434	1.090	1.479	.9329	.4100	25.6
.03400	.07630	.4794	.4457	.4980	1.1171	1.098	.8952	.9588	1.113	1.496	.9309	.4149	24.8
.03500	.07748	.4868	.4517	.5064	1.1209	1.092	.8921	.9737	1.135	1.513	.9289	.4196	24.19
.03600	.07867	.4943	.4577	.5147	1.1247	1.086	.8891	.9886	1.158	1.530	.9270	.4242	23.56
.03700	.07984	.5017	.4635	.5230	1.1285	1.080	.8861	1.003	1.180	1.547	.9250	.4287	22.97
.03800	.08100	.5090	.4691	.5312	1.1324	1.075	.8831	1.018	1.203	1.564	.9230	.4330	22.42
.03900	.08215	.5162	.4747	.5394	1.1362	1.069	.8801	1.032	1.226	1.582	.9211	.4372	21.90
.04000	.08329	.5233	.4802	.5475	1.1401	1.064	.8771	1.047	1.248	1.600	.9192	.4414	21.40
.04100	.08442	.5304	.4857	.5556	1.1440	1.059	.8741	1.061	1.271	1.617	.9172	.4455	20.92
.04200	.08553	.5374	.4911	.5637	1.1479	1.055	.8711	1.075	1.294	1.636	.9153	.4495	20.46
.04300	.08664	.5444	.4964	.5717	1.1518	1.050	.8688	1.089	1.317	1.654	.9133	.4534	20.03
.04400	.08774	.5513	.5015	.5796	1.1558	1.046	.8652	1.103	1.340	1.672	.9114	.4571	19.62
.04500	.08883	.5581	.5066	.5876	1.1599	1.042	.8621	1.116	1.363	1.691	.9095	.4607	19.23
.04600	.08991	.5649	.5116	.5954	1.1639	1.038	.8592	1.130	1.386	1.709	.9076	.4643	18.85
.04700	.09098	.5717	.5166	.6033	1.1679	1.034	.8562	1.143	1.409	1.728	.9057	.4679	18.49
.04800	.09205	.5784	.5215	.6111	1.1720	1.030	.8532	1.157	1.433	1.747	.9037	.4713	18.15
.04900	.09311	.5850	.5263	.6189	1.1760	1.026	.8503	1.170	1.456	1.766	.9018	.4746	17.82
.05000	.09416	.5916	.5310	.6267	1.1802	1.023	.8473	1.183	1.479	1.786	.8999	.4779	17.50
.05100	.09520	.5981	.5357	.6344	1.1843	1.019	.8444	1.196	1.503	1.805	.8980	.4811	17.19
.05200	.09623	.6046	.5403	.6421	1.1884	1.016	.8415	1.209	1.526	1.825	.8961	.4842	16.90
.05300	.09726	.6111	.5449	.6499	1.1926	1.013	.8385	1.222	1.550	1.845	.8943	.4873	16.62
.05400	.09829	.6176	.5494	.6575	1.1968	1.010	.8356	1.235	1.574	1.865	.8924	.4903	16.35
.05500	.09930	.6239	.5538	.6652	1.2011	1.007	.8326	1.248	1.598	1.885	.8905	.4932	16.09
.05600	.1003	.6303	.5582	.6729	1.2053	1.004	.8297	1.261	1.622	1.906	.8886	.4960	15.84
.05700	.1013	.6366	.5626	.6805	1.2096	1.001	.8267	1.273	1.646	1.926	.8867	.4988	15.60
.05800	.1023	.6428	.5668	.6880	1.2138	.9985	.8239	1.286	1.670	1.947	.8849	.5015	15.36
.05900	.1033	.6491	.5711	.6956	1.2181	.9958	.8209	1.298	1.695	1.968	.8830	.5042	15.13
.06000	.1043	.6553	.5753	.7033	1.2225	.9932	.8180	1.311	1.719	1.989	.8811	.5068	14.91
.06100	.1053	.6616	.5794	.7110	1.2270	.9907	.8150	1.323	1.744	2.011	.8792	.5094	14.70
.06200	.1063	.6678	.5834	.7187	1.2315	.9883	.8121	1.336	1.770	2.033	.8773	.5119	14.50
.06300	.1073	.6739	.5874	.7256	1.2355	.9860	.8093	1.348	1.795	2.055	.8755	.5143	14.30
.06400	.1082	.6799	.5914	.7335	1.2402	.9837	.8063	1.360	1.819	2.076	.8737	.5167	14.11
.06500	.1092	.6860	.5954	.7411	1.2447	.9815	.8035	1.372	1.845	2.098	.8719	.5191	13.92
.06600	.1101	.6920	.5993	.7486	1.2492	.9793	.8005	1.384	1.870	2.121	.8700	.5214	13.74
.06700	.1111	.6981	.6031	.7561	1.2537	.9772	.7977	1.396	1.896	2.144	.8682	.5236	13.57
.06800	.1120	.7037	.6069	.7633	1.2580	.9752	.7948	1.408	1.921	2.166	.8664	.5258	13.40
.06900	.1130	.7099	.6106	.7711	1.2628	.9732	.7919	1.420	1.948	2.189	.8646	.5279	13.24
.07000	.1139	.7157	.6144	.7783	1.2672	.9713	.7890	1.432	1.974	2.213	.8627	.5300	13.08
.07100	.1149	.7219	.6181	.7863	1.2721	.9694	.7861	1.444	2.000	2.236	.8609	.5321	12.92
.07200	.1158	.7277	.6217	.7937	1.2767	.9676	.7833	1.455	2.026	2.260	.8591	.5341	12.77
.07300	.1168	.7336	.6252	.8011	1.2813	.9658	.7804	1.467	2.053	2.284	.8572	.5360	12.62
.07400	.1177	.7395	.6289	.8088	1.2861	.9641	.7775	1.479	2.080	2.308	.8554	.5380	12.48
.07500	.1186	.7453	.6324	.8162	1.2908	.9624	.7747	1.490	2.107	2.332	.8537	.5399	12.34
.07600	.1195	.7511	.6359	.8237	1.2956	.9607	.7719	1.502	2.135	2.357	.8519	.5417	12.21
.07700	.1205	.7569	.6392	.8312	1.3004	.9591	.7690	1.514	2.162	2.382	.8501	.5435	12.08
.07800	.1214	.7625	.6427	.8386	1.3051	.9576	.7662	1.525	2.189	2.407	.8483	.5452	11.95
.07900	.1223	.7683	.6460	.8462	1.3100	.9562	.7634	1.537	2.217	2.432	.8465	.5469	11.83
.08000	.1232	.7741	.6493	.8538	1.3149	.9548	.7605	1.548	2.245	2.458	.8448	.5485	11.71
.08100	.1241	.7799	.6526	.8614	1.3198	.9534	.7577	1.560	2.274	2.484	.8430	.5501	11.59
.08200	.1251	.7854	.6558	.8687	1.3246	.9520	.7549	1.571	2.303	2.511	.8413	.5517	11.47
.08300	.1259	.7911	.6590	.8762	1.3295	.9506	.7522	1.583	2.331	2.537	.8395	.5533	11.36
.08400	.1268	.7967	.6622	.8837	1.3345	.9493	.7494	1.594	2.360	2.563	.8378	.5548	11.25
.08500	.1277	.8026	.6655	.8915	1.3397	.9481	.7464	1.605	2.389	2.590	.8360	.5563	11.14
.08600	.1286	.8080	.6685	.8989	1.3446	.9469	.7437	1.616	2.418	2.617	.8342	.5577	11.04
.08700	.1295	.8137	.6716	.9064	1.3497	.9457	.7409	1.628	2.448	2.644	.8325	.5591	10.94
.08800	.1304	.8193	.6747	.9141	1.3548	.9445	.7381	1.639	2.478	2.672	.8308	.5605	10.84
.08900	.1313	.8250	.6778	.9218	1.3600	.9433	.7353	1.650	2.508	2.700	.8290	.5619	10.74

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.09000	.1322	.8306	.6808	.9295	1.3653	.9422	.7324	1.661	2.538	2.728	.8273	.5632	10.65
.09100	.1331	.8363	.6838	.9372	1.3706	.9411	.7296	1.672	2.568	2.756	.8255	.5645	10.55
.09200	.1340	.8420	.6868	.9450	1.3759	.9401	.7268	1.684	2.599	2.785	.8238	.5658	10.46
.09300	.1349	.8474	.6897	.9525	1.3810	.9391	.7241	1.695	2.630	2.814	.8221	.5670	10.37
.09400	.1357	.8528	.6925	.9600	1.3862	.9381	.7214	1.706	2.662	2.843	.8204	.5682	10.29
.09500	.1366	.8583	.6953	.9677	1.3917	.9371	.7186	1.717	2.693	2.873	.8187	.5693	10.21
.09600	.1375	.8639	.6982	.9755	1.3970	.9362	.7158	1.728	2.726	2.903	.8170	.5704	10.12
.09700	.1384	.8694	.7011	.9832	1.4023	.9353	.7131	1.739	2.757	2.933	.8153	.5716	10.04
.09800	.1392	.8749	.7039	.9908	1.4077	.9344	.7104	1.750	2.790	2.963	.8136	.5727	9.962
.09900	.1401	.8803	.7066	.9985	1.4131	.9335	.7076	1.761	2.822	2.994	.8120	.5737	9.884
.1000	.1410	.8858	.7093	1.006	1.4187	.9327	.7049	1.772	2.855	3.025	.8103	.5747	9.808
.1010	.1419	.8913	.7120	1.014	1.4242	.9319	.7022	1.783	2.888	3.057	.8086	.5757	9.734
.1020	.1427	.8967	.7147	1.022	1.4297	.9311	.6994	1.793	2.922	3.088	.8069	.5766	9.661
.1030	.1436	.9023	.7173	1.030	1.4354	.9304	.6967	1.805	2.956	3.121	.8052	.5776	9.590
.1040	.1445	.9076	.7200	1.037	1.4410	.9297	.6940	1.815	2.990	3.153	.8036	.5785	9.519
.1050	.1453	.9130	.7226	1.045	1.4465	.9290	.6913	1.826	3.024	3.185	.8019	.5794	9.451
.1060	.1462	.9184	.7252	1.053	1.4523	.9282	.6886	1.837	3.059	3.218	.8003	.5803	9.384
.1070	.1470	.9239	.7277	1.061	1.4580	.9276	.6859	1.848	3.094	3.251	.7986	.5812	9.318
.1080	.1479	.9293	.7303	1.069	1.4638	.9269	.6833	1.858	3.128	3.284	.7970	.5820	9.254
.1090	.1488	.9343	.7327	1.076	1.4692	.9263	.6806	1.869	3.164	3.319	.7954	.5828	9.191
.1100	.1496	.9400	.7352	1.085	1.4752	.9257	.6779	1.880	3.201	3.353	.7937	.5836	9.129
.1110	.1505	.9456	.7377	1.093	1.4814	.9251	.6752	1.891	3.237	3.388	.7920	.5843	9.068
.1120	.1513	.9508	.7402	1.101	1.4871	.9245	.6725	1.902	3.274	3.423	.7904	.5850	9.009
.1130	.1522	.9563	.7426	1.109	1.4932	.9239	.6697	1.913	3.312	3.459	.7888	.5857	8.950
.1140	.1530	.9616	.7450	1.117	1.4990	.9234	.6671	1.923	3.348	3.494	.7872	.5864	8.891
.1150	.1539	.9670	.7474	1.125	1.5051	.9228	.6645	1.934	3.385	3.530	.7856	.5871	8.835
.1160	.1547	.9720	.7497	1.133	1.5108	.9223	.6619	1.944	3.423	3.566	.7840	.5878	8.780
.1170	.1556	.9775	.7520	1.141	1.5171	.9218	.6592	1.955	3.462	3.603	.7824	.5884	8.726
.1180	.1564	.9827	.7543	1.149	1.5230	.9214	.6566	1.966	3.501	3.641	.7808	.5890	8.673
.1190	.1573	.9882	.7566	1.157	1.5293	.9209	.6539	1.977	3.540	3.678	.7792	.5896	8.621
.1200	.1581	.9936	.7589	1.165	1.5356	.9204	.6512	1.987	3.579	3.716	.7776	.5902	8.569
.1210	.1590	.9989	.7612	1.174	1.5418	.9200	.6486	1.998	3.620	3.755	.7760	.5907	8.518
.1220	.1598	1.004	.7634	1.182	1.5479	.9196	.6460	2.008	3.659	3.793	.7745	.5913	8.468
.1230	.1607	1.010	.7656	1.190	1.5546	.9192	.6433	2.019	3.699	3.832	.7729	.5918	8.419
.1240	.1615	1.015	.7678	1.198	1.5605	.9189	.6407	2.030	3.740	3.871	.7713	.5922	8.371
.1250	.1624	1.020	.7700	1.207	1.5674	.9186	.6381	2.041	3.782	3.912	.7698	.5926	8.324
.1260	.1632	1.025	.7721	1.215	1.5734	.9182	.6356	2.051	3.824	3.952	.7682	.5931	8.278
.1270	.1640	1.030	.7742	1.223	1.5795	.9178	.6331	2.061	3.865	3.992	.7667	.5936	8.233
.1280	.1649	1.036	.7763	1.231	1.5862	.9175	.6305	2.072	3.907	4.033	.7652	.5940	8.189
.1290	.1657	1.041	.7783	1.240	1.5927	.9172	.6279	2.082	3.950	4.074	.7637	.5944	8.146
.1300	.1665	1.046	.7804	1.248	1.5990	.9169	.6254	2.093	3.992	4.115	.7621	.5948	8.103
.1310	.1674	1.052	.7824	1.257	1.6060	.9166	.6228	2.104	4.036	4.158	.7606	.5951	8.061
.1320	.1682	1.057	.7844	1.265	1.6124	.9164	.6202	2.114	4.080	4.201	.7591	.5954	8.020
.1330	.1691	1.062	.7865	1.273	1.6191	.9161	.6176	2.125	4.125	4.245	.7575	.5958	7.978
.1340	.1699	1.068	.7885	1.282	1.6260	.9158	.6150	2.135	4.169	4.288	.7560	.5961	7.937
.1350	.1708	1.073	.7905	1.291	1.633	.9156	.6123	2.146	4.217	4.334	.7545	.5964	7.897
.1360	.1716	1.078	.7925	1.300	1.640	.9154	.6098	2.156	4.262	4.378	.7530	.5967	7.857
.1370	.1724	1.084	.7945	1.308	1.647	.9152	.6073	2.167	4.309	4.423	.7515	.5969	7.819
.1380	.1733	1.089	.7964	1.317	1.654	.9150	.6047	2.177	4.355	4.468	.7500	.5972	7.781
.1390	.1741	1.094	.7983	1.326	1.660	.9148	.6022	2.188	4.402	4.514	.7485	.5975	7.744
.1400	.1749	1.099	.8002	1.334	1.667	.9146	.5998	2.198	4.450	4.561	.7471	.5978	7.707
.1410	.1758	1.105	.8021	1.343	1.675	.9144	.5972	2.209	4.498	4.607	.7456	.5980	7.671
.1420	.1766	1.110	.8039	1.352	1.681	.9142	.5947	2.219	4.546	4.654	.7441	.5982	7.636
.1430	.1774	1.115	.8057	1.360	1.688	.9141	.5923	2.230	4.595	4.663	.7426	.5984	7.602
.1440	.1783	1.120	.8076	1.369	1.696	.9140	.5898	2.240	4.644	4.751	.7412	.5986	7.567
.1450	.1791	1.125	.8094	1.378	1.703	.9139	.5873	2.251	4.695	4.800	.7397	.5987	7.533
.1460	.1800	1.131	.8112	1.388	1.710	.9137	.5847	2.261	4.746	4.850	.7382	.5989	7.499
.1470	.1808	1.136	.8131	1.397	1.718	.9136	.5822	2.272	4.798	4.901	.7368	.5990	7.465
.1480	.1816	1.141	.8149	1.405	1.725	.9135	.5798	2.282	4.847	4.951	.7354	.5992	7.432
.1490	.1825	1.146	.8166	1.415	1.732	.9134	.5773	2.293	4.901	5.001	.7339	.5993	7.400

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.1500	.1833	1.152	.8183	1.424	1.740	.9133	.5748	2.303	4.954	5.054	.7325	.5994	7.369
.1510	.1841	1.157	.8200	1.433	1.747	.9133	.5723	2.314	5.007	5.106	.7311	.5994	7.339
.1520	.1850	1.162	.8217	1.442	1.755	.9132	.5699	2.324	5.061	5.159	.7296	.5995	7.309
.1530	.1858	1.167	.8234	1.451	1.762	.9132	.5675	2.335	5.115	5.212	.7282	.5996	7.279
.1540	.1866	1.173	.8250	1.460	1.770	.9132	.5651	2.345	5.169	5.265	.7268	.5996	7.250
.1550	.1875	1.178	.8267	1.469	1.777	.9131	.5627	2.356	5.225	5.320	.7254	.5997	7.221
.1560	.1883	1.183	.8284	1.479	1.785	.9130	.5602	2.366	5.283	5.376	.7240	.5998	7.191
.1570	.1891	1.188	.8301	1.488	1.793	.9129	.5577	2.377	5.339	5.432	.7226	.5999	7.162
.1580	.1900	1.194	.8317	1.498	1.801	.9130	.5552	2.387	5.398	5.490	.7212	.5998	7.134
.1590	.1908	1.199	.8333	1.507	1.809	.9130	.5528	2.398	5.454	5.544	.7198	.5998	7.107
.1600	.1917	1.204	.8349	1.517	1.817	.9130	.5504	2.408	5.513	5.603	.7184	.5998	7.079
.1610	.1925	1.209	.8365	1.527	1.825	.9130	.5480	2.419	5.571	5.660	.7171	.5998	7.052
.1620	.1933	1.215	.8381	1.536	1.833	.9130	.5456	2.429	5.630	5.718	.7157	.5998	7.026
.1630	.1941	1.220	.8396	1.546	1.841	.9130	.5432	2.440	5.690	5.777	.7144	.5998	7.000
.1640	.1950	1.225	.8411	1.555	1.849	.9130	.5409	2.450	5.751	5.837	.7130	.5998	6.975
.1650	.1958	1.230	.8427	1.565	1.857	.9131	.5385	2.461	5.813	5.898	.7117	.5997	6.949
.1660	.1966	1.235	.8442	1.574	1.865	.9132	.5362	2.471	5.874	5.959	.7103	.5996	6.924
.1670	.1975	1.240	.8457	1.584	1.873	.9132	.5339	2.482	5.938	6.021	.7090	.5996	6.900
.1680	.1983	1.246	.8472	1.594	1.882	.9133	.5315	2.492	6.003	6.085	.7076	.5995	6.876
.1690	.1992	1.251	.8486	1.604	1.890	.9133	.5291	2.503	6.066	6.148	.7063	.5994	6.853
.1700	.2000	1.257	.8501	1.614	1.899	.9134	.5267	2.513	6.130	6.212	.7050	.5993	6.830
.1710	.2008	1.262	.8515	1.624	1.907	.9135	.5243	2.523	6.197	6.275	.7036	.5992	6.807
.1720	.2017	1.267	.8529	1.634	1.915	.9136	.5220	2.534	6.262	6.342	.7023	.5991	6.784
.1730	.2025	1.272	.8544	1.644	1.924	.9137	.5197	2.544	6.329	6.407	.7010	.5989	6.761
.1740	.2033	1.277	.8558	1.654	1.933	.9138	.5174	2.555	6.395	6.473	.6997	.5988	6.738
.1750	.2042	1.282	.8572	1.664	1.941	.9139	.5151	2.565	6.465	6.541	.6984	.5987	6.716
.1760	.2050	1.288	.8586	1.675	1.951	.9140	.5127	2.576	6.534	6.610	.6971	.5985	6.694
.1770	.2058	1.293	.8600	1.685	1.959	.9141	.5104	2.586	6.603	6.679	.6958	.5984	6.672
.1780	.2066	1.298	.8614	1.695	1.968	.9142	.5081	2.597	6.672	6.747	.6946	.5982	6.651
.1790	.2075	1.304	.8627	1.706	1.977	.9144	.5058	2.607	6.744	6.818	.6933	.5980	6.631
.1800	.2083	1.309	.8640	1.716	1.986	.9145	.5036	2.618	6.818	6.891	.6920	.5979	6.611
.1810	.2092	1.314	.8653	1.727	1.995	.9146	.5013	2.629	6.890	6.963	.6907	.5977	6.591
.1820	.2100	1.320	.8666	1.737	2.004	.9148	.4990	2.639	6.963	7.035	.6895	.5975	6.571
.1830	.2108	1.325	.8680	1.748	2.013	.9149	.4967	2.650	7.038	7.109	.6882	.5974	6.550
.1840	.2117	1.330	.8693	1.758	2.022	.9150	.4945	2.660	7.113	7.183	.6870	.5972	6.530
.1850	.2125	1.335	.8706	1.769	2.032	.9152	.4922	2.671	7.191	7.260	.6857	.5969	6.511
.1860	.2134	1.341	.8718	1.780	2.041	.9154	.4899	2.681	7.267	7.336	.6845	.5967	6.492
.1870	.2142	1.346	.8731	1.791	2.051	.9155	.4876	2.692	7.345	7.412	.6832	.5965	6.474
.1880	.2150	1.351	.8743	1.801	2.060	.9157	.4854	2.702	7.421	7.488	.6820	.5963	6.456
.1890	.2159	1.356	.8755	1.812	2.070	.9159	.4832	2.712	7.500	7.566	.6808	.5961	6.438
.1900	.2167	1.362	.8767	1.823	2.079	.9161	.4809	2.723	7.581	7.647	.6796	.5958	6.421
.1910	.2176	1.367	.8779	1.834	2.089	.9163	.4787	2.734	7.663	7.728	.6784	.5955	6.403
.1920	.2184	1.372	.8791	1.845	2.099	.9165	.4765	2.744	7.746	7.810	.6772	.5952	6.385
.1930	.2192	1.377	.8803	1.856	2.108	.9167	.4743	2.755	7.827	7.891	.6760	.5950	6.368
.1940	.2201	1.383	.8815	1.867	2.118	.9169	.4721	2.765	7.911	7.974	.6748	.5948	6.351
.1950	.2209	1.388	.8827	1.879	2.128	.9170	.4699	2.776	7.996	8.059	.6736	.5946	6.334
.1960	.2218	1.393	.8839	1.890	2.138	.9172	.4677	2.787	8.083	8.145	.6724	.5944	6.317
.1970	.2226	1.399	.8850	1.901	2.148	.9174	.4655	2.797	8.167	8.228	.6712	.5941	6.300
.1980	.2234	1.404	.8862	1.913	2.158	.9176	.4633	2.808	8.256	8.316	.6700	.5938	6.284
.1990	.2243	1.409	.8873	1.924	2.169	.9179	.4611	2.819	8.346	8.406	.6689	.5935	6.268
.2000	.2251	1.414	.8884	1.935	2.178	.9181	.4590	2.829	8.436	8.495	.6677	.5932	6.253
.2010	.2260	1.420	.8895	1.947	2.189	.9183	.4569	2.840	8.524	8.583	.6666	.5929	6.237
.2020	.2268	1.425	.8906	1.959	2.199	.9186	.4547	2.850	8.616	8.674	.6654	.5926	6.222
.2030	.2277	1.430	.8917	1.970	2.210	.9188	.4526	2.861	8.708	8.766	.6642	.5923	6.206
.2040	.2285	1.436	.8928	1.982	2.220	.9190	.4504	2.872	8.803	8.860	.6631	.5920	6.191
.2050	.2293	1.441	.8939	1.994	2.231	.9193	.4483	2.882	8.897	8.953	.6620	.5917	6.176
.2060	.2302	1.446	.8950	2.006	2.242	.9195	.4462	2.893	8.994	9.050	.6608	.5914	6.161
.2070	.2310	1.451	.8960	2.017	2.252	.9197	.4441	2.903	9.090	9.144	.6597	.5911	6.147
.2080	.2319	1.457	.8971	2.030	2.263	.9200	.4419	2.914	9.187	9.240	.6586	.5908	6.133
.2090	.2328	1.462	.8981	2.042	2.274	.9202	.4398	2.925	9.288	9.342	.6574	.5905	6.119

Table C-1. Continued

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.2100	.2336	1.468	.8991	2.055	2.285	.9205	.4377	2.936	9.389	9.442	.6563	.5901	6.105
.2110	.2344	1.473	.9001	2.066	2.295	.9207	.4357	2.946	9.490	9.542	.6552	.5898	6.091
.2120	.2353	1.479	.9011	2.079	2.307	.9210	.4336	2.957	9.590	9.642	.6541	.5894	6.077
.2130	.2361	1.484	.9021	2.091	2.318	.9213	.4315	2.967	9.693	9.744	.6531	.5891	6.064
.2140	.2370	1.489	.9031	2.103	2.329	.9215	.4294	2.978	9.796	9.847	.6520	.5888	6.051
.2150	.2378	1.494	.9041	2.115	2.340	.9218	.4274	2.989	9.902	9.952	.6509	.5884	6.037
.2160	.2387	1.500	.9051	2.128	2.351	.9221	.4253	2.999	10.01	10.06	.6498	.5881	6.024
.2170	.2395	1.506	.9061	2.142	2.364	.9223	.4232	3.010	10.12	10.17	.6488	.5878	6.011
.2180	.2404	1.511	.9070	2.154	2.375	.9226	.4211	3.021	10.23	10.28	.6477	.5874	5.999
.2190	.2412	1.516	.9079	2.166	2.386	.9228	.4191	3.031	10.34	10.38	.6467	.5871	5.987
.2200	.2421	1.521	.9088	2.178	2.397	.9231	.4171	3.042	10.45	10.50	.6456	.5868	5.975
.2210	.2429	1.526	.9097	2.192	2.409	.9234	.4151	3.052	10.56	10.61	.6446	.5864	5.963
.2220	.2438	1.532	.9107	2.204	2.421	.9236	.4131	3.063	10.68	10.72	.6436	.5861	5.951
.2230	.2446	1.537	.9116	2.218	2.433	.9239	.4111	3.074	10.79	10.84	.6425	.5857	5.939
.2240	.2455	1.542	.9125	2.230	2.444	.9242	.4091	3.085	10.91	10.95	.6414	.5854	5.927
.2250	.2463	1.548	.9134	2.244	2.457	.9245	.4071	3.095	11.02	11.07	.6404	.5850	5.915
.2260	.2472	1.553	.9143	2.257	2.469	.9248	.4051	3.106	11.15	11.19	.6394	.5846	5.903
.2270	.2481	1.559	.9152	2.271	2.481	.9251	.4031	3.117	11.27	11.31	.6383	.5842	5.891
.2280	.2489	1.564	.9161	2.284	2.493	.9254	.4011	3.128	11.39	11.44	.6373	.5838	5.880
.2290	.2498	1.569	.9170	2.297	2.506	.9258	.3991	3.138	11.51	11.56	.6363	.5834	5.869
.2300	.2506	1.575	.9178	2.311	2.518	.9261	.3971	3.149	11.64	11.68	.6353	.5830	5.858
.2310	.2515	1.580	.9186	2.325	2.531	.9264	.3952	3.160	11.77	11.81	.6343	.5826	5.848
.2320	.2523	1.585	.9194	2.338	2.543	.9267	.3932	3.171	11.90	11.93	.6333	.5823	5.838
.2330	.2532	1.591	.9203	2.352	2.556	.9270	.3912	3.182	12.03	12.07	.6323	.5819	5.827
.2340	.2540	1.596	.9211	2.366	2.569	.9273	.3893	3.192	12.15	12.19	.6313	.5815	5.816
.2350	.2549	1.602	.9219	2.380	2.581	.9276	.3874	3.203	12.29	12.33	.6304	.5811	5.806
.2360	.2558	1.607	.9227	2.393	2.594	.9279	.3855	3.214	12.43	12.47	.6294	.5807	5.796
.2370	.2566	1.612	.9235	2.408	2.607	.9282	.3836	3.225	12.55	12.59	.6284	.5804	5.786
.2380	.2575	1.618	.9243	2.422	2.620	.9285	.3816	3.236	12.69	12.73	.6275	.5800	5.776
.2390	.2584	1.623	.9251	2.436	2.634	.9288	.3797	3.247	12.83	12.87	.6265	.5796	5.766
.2400	.2592	1.629	.9259	2.450	2.647	.9291	.3779	3.257	12.97	13.01	.6256	.5792	5.756
.2410	.2601	1.634	.9267	2.464	2.660	.9294	.3760	3.268	13.11	13.15	.6246	.5788	5.746
.2420	.2610	1.640	.9275	2.480	2.674	.9298	.3741	3.279	13.26	13.30	.6237	.5784	5.736
.2430	.2618	1.645	.9282	2.494	2.687	.9301	.3722	3.290	13.40	13.44	.6228	.5780	5.727
.2440	.2627	1.650	.9289	2.508	2.700	.9304	.3704	3.301	13.55	13.59	.6218	.5776	5.718
.2450	.2635	1.656	.9296	2.523	2.714	.9307	.3685	3.312	13.70	13.73	.6209	.5272	5.710
.2460	.2644	1.661	.9304	2.538	2.728	.9310	.3666	3.323	13.85	13.88	.6200	.5768	5.701
.2470	.2653	1.667	.9311	2.553	2.742	.9314	.3648	3.334	14.00	14.04	.6191	.5764	5.692
.2480	.2661	1.672	.9318	2.568	2.755	.9317	.3629	3.344	14.15	14.19	.6182	.5760	5.684
.2490	.2670	1.678	.9325	2.583	2.770	.9320	.3610	3.355	14.31	14.35	.6173	.5756	5.675
.2500	.2679	1.683	.9332	2.599	2.784	.9323	.3592	3.367	14.47	14.51	.6164	.5752	5.667
.2510	.2687	1.689	.9339	2.614	2.798	.9327	.3574	3.377	14.62	14.66	.6155	.5748	5.658
.2520	.2696	1.694	.9346	2.629	2.813	.9330	.3556	3.388	14.79	14.82	.6146	.5744	5.650
.2530	.2705	1.700	.9353	2.645	2.828	.9333	.3537	3.399	14.95	14.99	.6137	.5740	5.641
.2540	.2714	1.705	.9360	2.660	2.842	.9336	.3519	3.410	15.12	15.15	.6128	.5736	5.633
.2550	.2722	1.711	.9367	2.676	2.856	.9340	.3501	3.421	15.29	15.32	.6120	.5732	5.624
.2560	.2731	1.716	.9374	2.691	2.871	.9343	.3483	3.432	15.45	15.49	.6111	.5728	5.616
.2570	.2740	1.722	.9381	2.707	2.886	.9346	.3465	3.443	15.63	15.66	.6102	.5724	5.608
.2580	.2749	1.727	.9388	2.723	2.901	.9349	.3447	3.454	15.80	15.83	.6093	.5720	5.600
.2590	.2757	1.732	.9394	2.739	2.916	.9353	.3430	3.465	15.97	16.00	.6085	.5716	5.592
.2600	.2766	1.738	.9400	2.755	2.931	.9356	.3412	3.476	16.15	16.18	.6076	.5712	5.585
.2610	.2775	1.744	.9406	2.772	2.946	.9360	.3394	3.487	16.33	16.36	.6068	.5707	5.578
.2620	.2784	1.749	.9412	2.788	2.962	.9363	.3376	3.498	16.51	16.54	.6060	.5703	5.571
.2630	.2792	1.755	.9418	2.804	2.977	.9367	.3359	3.509	16.69	16.73	.6052	.5699	5.563
.2640	.2801	1.760	.9425	2.820	2.992	.9370	.3342	3.520	16.88	16.91	.6043	.5695	5.556
.2650	.2810	1.766	.9431	2.837	3.008	.9373	.3325	3.531	17.07	17.10	.6035	.5691	5.548
.2660	.2819	1.771	.9437	2.853	3.023	.9377	.3308	3.542	17.26	17.28	.6027	.5687	5.541
.2670	.2827	1.776	.9443	2.870	3.039	.9380	.3291	3.553	17.45	17.45	.6018	.5683	5.534
.2680	.2836	1.782	.9449	2.886	3.055	.9383	.3274	3.564	17.64	17.67	.6010	.5679	5.527
.2690	.2845	1.788	.9455	2.904	3.071	.9386	.3256	3.575	17.84	17.87	.6002	.5675	5.520

Table C-1. Continued

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.2700	.2854	1.793	.9461	2.921	3.088	.9390	.3239	3.587	18.04	18.07	.5994	.5671	5.513
.2710	.2863	1.799	.9467	2.938	3.104	.9393	.3222	3.598	18.24	18.27	.5986	.5667	5.506
.2720	.2872	1.804	.9473	2.956	3.120	.9396	.3205	3.610	18.46	18.49	.5978	.5663	5.499
.2730	.2880	1.810	.9478	2.973	3.136	.9400	.3189	3.620	18.65	18.67	.5971	.5659	5.493
.2740	.2889	1.815	.9484	2.990	3.153	.9403	.3172	3.631	18.86	18.89	.5963	.5655	5.486
.2750	.2898	1.821	.9490	3.008	3.170	.9406	.3155	3.642	19.07	19.10	.5955	.5651	5.480
.2760	.2907	1.826	.9495	3.025	3.186	.9410	.3139	3.653	19.28	19.30	.5947	.5647	5.474
.2770	.2916	1.832	.9500	3.043	3.203	.9413	.3122	3.664	19.49	19.51	.5940	.5643	5.468
.2780	.2924	1.837	.9505	3.061	3.220	.9416	.3106	3.675	19.71	19.74	.5932	.5639	5.462
.2790	.2933	1.843	.9511	3.079	3.237	.9420	.3089	3.686	19.93	19.96	.5925	.5635	5.456
.2800	.2942	1.849	.9516	3.097	3.254	.9423	.3073	3.697	20.16	20.18	.5917	.5631	5.450
.2810	.2951	1.854	.9521	3.115	3.272	.9426	.3057	3.709	20.39	20.41	.5910	.5627	5.444
.2820	.2960	1.860	.9526	3.133	3.289	.9430	.3040	3.720	20.62	20.64	.5902	.5623	5.438
.2830	.2969	1.866	.9532	3.152	3.307	.9433	.3024	3.731	20.85	20.87	.5895	.5619	5.432
.2840	.2978	1.871	.9537	3.171	3.325	.9436	.3008	3.742	21.09	21.11	.5887	.5615	5.426
.2850	.2987	1.877	.9542	3.190	3.343	.9440	.2992	3.754	21.33	21.35	.5880	.5611	5.420
.2860	.2996	1.882	.9547	3.209	3.361	.9443	.2976	3.765	21.57	21.59	.5873	.5607	5.414
.2870	.3005	1.888	.9552	3.228	3.379	.9446	.2959	3.776	21.82	21.84	.5866	.5603	5.409
.2880	.3014	1.893	.9557	3.246	3.396	.9449	.2944	3.787	22.05	22.07	.5859	.5600	5.403
.2890	.3022	1.899	.9562	3.264	3.414	.9452	.2929	3.798	22.30	22.32	.5852	.5596	5.397
.2900	.3031	1.905	.9567	3.284	3.433	.9456	.2913	3.809	22.54	22.57	.5845	.5592	5.392
.2910	.3040	1.910	.9572	3.303	3.451	.9459	.2898	3.821	22.81	22.83	.5838	.5588	5.386
.2920	.3049	1.916	.9577	3.323	3.471	.9463	.2882	3.832	23.07	23.09	.5831	.5584	5.380
.2930	.3058	1.922	.9581	3.343	3.490	.9466	.2866	3.843	23.33	23.35	.5824	.5580	5.375
.2940	.3067	1.927	.9585	3.362	3.508	.9469	.2851	3.855	23.60	23.62	.5817	.5576	5.371
.2950	.3076	1.933	.9590	3.382	3.527	.9473	.2835	3.866	23.86	23.88	.5810	.5572	5.366
.2960	.3085	1.938	.9594	3.402	3.546	.9476	.2820	3.877	24.12	24.15	.5804	.5568	5.361
.2970	.3094	1.944	.9599	3.422	3.565	.9480	.2805	3.888	24.40	24.42	.5797	.5564	5.356
.2980	.3103	1.950	.9603	3.442	3.585	.9483	.2790	3.900	24.68	24.70	.5790	.5560	5.351
.2990	.3112	1.955	.9607	3.462	3.604	.9486	.2775	3.911	24.96	24.98	.5784	.5556	5.347
.3000	.3121	1.961	.9611	3.483	3.624	.9490	.2760	3.922	25.24	25.26	.5777	.5552	5.342
.3010	.3130	1.967	.9616	3.503	3.643	.9493	.2745	3.933	25.53	25.55	.5771	.5549	5.337
.3020	.3139	1.972	.9620	3.524	3.663	.9496	.2730	3.945	25.82	25.83	.5764	.5545	5.332
.3030	.3148	1.978	.9624	3.545	3.683	.9499	.2715	3.956	26.12	26.14	.5758	.5541	5.328
.3040	.3157	1.984	.9629	3.566	3.703	.9502	.2700	3.968	26.42	26.44	.5751	.5538	5.323
.3050	.3166	1.989	.9633	3.587	3.724	.9505	.2685	3.979	26.72	26.74	.5745	.5534	5.318
.3060	.3175	1.995	.9637	3.609	3.745	.9509	.2670	3.990	27.02	27.04	.5739	.5530	5.314
.3070	.3184	2.001	.9641	3.630	3.765	.9512	.2656	4.002	27.33	27.35	.5732	.5527	5.309
.3080	.3193	2.007	.9645	3.651	3.786	.9515	.2641	4.013	27.65	27.66	.5726	.5523	5.305
.3090	.3202	2.012	.9649	3.673	3.806	.9518	.2627	4.024	27.96	27.98	.5720	.5519	5.300
.3100	.3211	2.018	.9653	3.694	3.827	.9522	.2613	4.036	28.28	28.30	.5714	.5515	5.296
.3110	.3220	2.023	.9656	3.716	3.848	.9525	.2599	4.047	28.60	28.62	.5708	.5511	5.292
.3120	.3230	2.029	.9660	3.738	3.870	.9528	.2584	4.058	28.93	28.95	.5701	.5507	5.288
.3130	.3239	2.035	.9664	3.760	3.891	.9531	.2570	4.070	29.27	29.28	.5695	.5504	5.284
.3140	.3248	2.041	.9668	3.782	3.912	.9535	.2556	4.081	29.60	29.62	.5689	.5500	5.280
.3150	.3257	2.046	.9672	3.805	3.934	.9538	.2542	4.093	29.94	29.96	.5683	.5497	5.276
.3160	.3266	2.052	.9676	3.828	3.956	.9541	.2528	4.104	30.29	30.31	.5678	.5494	5.272
.3170	.3275	2.058	.9679	3.851	3.978	.9544	.2514	4.116	30.64	30.65	.5672	.5490	5.268
.3180	.3284	2.063	.9682	3.873	4.000	.9547	.2500	4.127	30.99	31.00	.5666	.5486	5.264
.3190	.3294	2.069	.9686	3.896	4.022	.9550	.2486	4.139	31.35	31.37	.5660	.5483	5.260
.3200	.3302	2.075	.9690	3.919	4.045	.9553	.2472	4.150	31.71	31.72	.5655	.5479	5.256
.3210	.3311	2.081	.9693	3.943	4.068	.9556	.2459	4.161	32.07	32.08	.5649	.5476	5.252
.3220	.3321	2.086	.9696	3.966	4.090	.9559	.2445	4.173	32.44	32.46	.5643	.5472	5.249
.3230	.3330	2.092	.9700	3.990	4.114	.9562	.2431	4.185	32.83	32.84	.5637	.5468	5.245
.3240	.3339	2.098	.9703	4.014	4.136	.9565	.2418	4.196	33.20	33.22	.5632	.5465	5.241
.3250	.3349	2.104	.9707	4.038	4.160	.9568	.2404	4.208	33.60	33.61	.5627	.5462	5.237
.3260	.3357	2.110	.9710	4.061	4.183	.9571	.2391	4.219	33.97	33.99	.5621	.5458	5.234
.3270	.3367	2.115	.9713	4.085	4.206	.9574	.2378	4.231	34.37	34.38	.5616	.5455	5.231
.3280	.3376	2.121	.9717	4.110	4.230	.9577	.2364	4.242	34.77	34.79	.5610	.5451	5.227
.3290	.3385	2.127	.9720	4.135	4.254	.9580	.2351	4.254	35.18	35.19	.5605	.5448	5.223

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H_o'	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.3300	.3394	2.133	.9723	4.159	4.277	.9583	.2338	4.265	35.58	35.59	.5599	.5444	5.220
.3310	.3403	2.138	.9726	4.184	4.301	.9586	.2325	4.277	35.99	36.00	.5594	.5441	5.217
.3320	.3413	2.144	.9729	4.209	4.326	.9589	.2312	4.288	36.42	36.43	.5589	.5438	5.214
.3330	.3422	2.150	.9732	4.234	4.350	.9592	.2299	4.300	36.84	36.85	.5584	.5434	5.210
.3340	.3431	2.156	.9735	4.259	4.375	.9595	.2286	4.311	37.25	37.27	.5578	.5431	5.207
.3350	.3440	2.161	.9738	4.284	4.399	.9598	.2273	4.323	37.70	37.72	.5573	.5427	5.204
.3360	.3449	2.167	.9741	4.310	4.424	.9601	.2260	4.335	38.14	38.15	.5568	.5424	5.201
.3370	.3459	2.173	.9744	4.336	4.450	.9604	.2247	4.346	38.59	38.60	.5563	.5421	5.198
.3380	.3468	2.179	.9747	4.361	4.474	.9607	.2235	4.358	39.02	39.04	.5558	.5417	5.194
.3390	.3477	2.185	.9750	4.388	4.500	.9610	.2222	4.369	39.48	39.49	.5553	.5414	5.191
.3400	.3468	2.190	.9753	4.413	4.525	.9613	.2210	4.381	39.95	39.96	.5548	.5411	5.188
.3410	.3495	2.196	.9756	4.439	4.550	.9615	.2198	4.392	40.40	40.41	.5544	.5408	5.185
.3420	.3504	2.202	.9758	4.466	4.576	.9618	.2185	4.404	40.87	40.89	.5539	.5405	5.182
.3430	.3514	2.208	.9761	4.492	4.602	.9621	.2173	4.416	41.36	41.37	.5534	.5402	5.179
.3440	.3523	2.214	.9764	4.521	4.630	.9623	.2160	4.427	41.85	41.84	.5529	.5399	5.176
.3450	.3532	2.220	.9767	4.547	4.656	.9626	.2148	4.439	42.33	42.34	.5524	.5396	5.173
.3460	.3542	2.225	.9769	4.575	4.682	.9629	.2136	4.451	42.83	42.84	.5519	.5392	5.171
.3470	.3551	2.231	.9772	4.602	4.709	.9632	.2124	4.462	43.34	43.35	.5515	.5389	5.168
.3480	.3560	2.237	.9775	4.629	4.736	.9635	.2111	4.474	43.85	43.86	.5510	.5386	5.165
.3490	.3570	2.243	.9777	4.657	4.763	.9638	.2099	4.486	44.37	44.40	.5505	.5383	5.162
.3500	.3579	2.249	.9780	4.685	4.791	.9640	.2087	4.498	44.89	44.80	.5501	.5380	5.159
.3510	.3588	2.255	.9782	4.713	4.818	.9643	.2076	4.509	45.42	45.43	.5496	.5377	5.157
.3520	.3598	2.260	.9785	4.741	4.845	.9646	.2064	4.521	45.95	45.96	.5492	.5374	5.154
.3530	.3607	2.266	.9787	4.770	4.873	.9648	.2052	4.533	46.50	46.51	.5487	.5371	5.152
.3540	.3616	2.272	.9790	4.798	4.901	.9651	.2040	4.544	47.03	47.04	.5483	.5368	5.149
.3550	.3625	2.278	.9792	4.827	4.929	.9654	.2029	4.556	47.59	47.60	.5479	.5365	5.147
.3560	.3635	2.284	.9795	4.856	4.957	.9657	.2017	4.568	48.15	48.16	.5474	.5362	5.144
.3570	.3644	2.290	.9797	4.885	4.987	.9659	.2005	4.579	48.72	48.73	.5470	.5359	5.141
.3580	.3653	2.296	.9799	4.914	5.015	.9662	.1994	4.591	49.29	49.30	.5466	.5356	5.139
.3590	.3663	2.301	.9801	4.944	5.044	.9665	.1983	4.603	49.88	49.89	.5461	.5353	5.137
.3600	.3672	2.307	.9804	4.974	5.072	.9667	.1972	4.615	50.47	50.48	.5457	.5350	5.134
.3610	.3682	2.313	.9806	5.004	5.103	.9670	.1960	4.627	51.08	51.09	.5453	.5347	5.132
.3620	.3691	2.319	.9808	5.034	5.132	.9673	.1949	4.638	51.67	51.67	.5449	.5344	5.130
.3630	.3700	2.325	.9811	5.063	5.161	.9675	.1938	4.650	52.27	52.28	.5445	.5342	5.127
.3640	.3709	2.331	.9813	5.094	5.191	.9677	.1926	4.661	52.89	52.90	.5441	.5339	5.125
.3650	.3719	2.337	.9815	5.124	5.221	.9680	.1915	4.673	53.52	53.53	.5437	.5336	5.123
.3660	.3728	2.342	.9817	5.155	5.251	.9683	.1904	4.685	54.15	54.16	.5433	.5333	5.121
.3670	.3737	2.348	.9819	5.186	5.281	.9686	.1894	4.697	54.78	54.79	.5429	.5330	5.118
.3680	.3747	2.354	.9821	5.217	5.312	.9688	.1883	4.708	55.42	55.43	.5425	.5327	5.116
.3690	.3756	2.360	.9823	5.248	5.343	.9690	.1872	4.720	56.09	56.10	.5421	.5325	5.114
.3700	.3766	2.366	.9825	5.280	5.374	.9693	.1861	4.732	56.76	56.77	.5417	.5322	5.112
.3710	.3775	2.372	.9827	5.312	5.406	.9696	.1850	4.744	57.43	57.44	.5413	.5319	5.110
.3720	.3785	2.378	.9830	5.345	5.438	.9698	.1839	4.756	58.13	58.14	.5409	.5317	5.107
.3730	.3794	2.384	.9832	5.377	5.469	.9700	.1828	4.768	58.82	58.83	.5405	.5314	5.105
.3740	.3804	2.390	.9834	5.410	5.502	.9702	.1818	4.780	59.52	59.53	.5402	.5312	5.103
.3750	.3813	2.396	.9835	5.443	5.534	.9705	.1807	4.792	60.24	60.25	.5398	.5309	5.101
.3760	.3822	2.402	.9837	5.475	5.566	.9707	.1797	4.803	60.95	60.95	.5394	.5306	[illegible]
.3770	.3832	2.408	.9839	5.508	5.598	.9709	.1786	4.815	61.68	61.68	.5390	.5304	[illegible]
.3780	.3841	2.413	.9841	5.541	5.631	.9712	.1776	4.827	62.41	62.42	.5387	.5301	[illegible]
.3790	.3850	2.419	.9843	5.572	5.661	.9714	.1766	4.838	63.13	63.14	.5383	.5299	[illegible]
.3800	.3860	2.425	.9845	5.609	5.697	.9717	.1756	4.851	63.91	63.91	.5380	.5296	[illegible]
.3810	.3869	2.431	.9847	5.643	5.731	.9719	.1745	4.862	64.67	64.67	.5376	.5294	[illegible]
.3820	.3879	2.437	.9848	5.677	5.765	.9721	.1735	4.875	65.45	65.46	.5372	.5291	[illegible]
3830	.3888	2.443	.9850	5.712	5.798	.9724	.1725	4.885	66.16	66.17	.5369	.5288	[illegible]
3840	.3898	2.449	.9852	5.746	5.833	.9726	.1715	4.898	67.02	67.03	.5365	.5286	[illegible]
.3850	.3907	2.455	.9854	5.780	5.866	.9728	.1705	4.910	67.80	67.81	.5362	.5284	[illegible]
.3860	.3917	2.461	.9855	5.814	5.900	.9730	.1695	4.922	68.61	68.62	.5359	.5281	[illegible]
3870	.3926	2.467	.9857	5.850	5.935	.9732	.1685	4.934	69.45	69.46	.5355	.5279	[illegible]
3880	.3936	2.473	.9859	5.886	5.970	.9735	.1675	4.946	70.28	70.29	.5352	.5276	[illegible]
.3890	.3945	2.479	.9860	5.921	6.005	.9737	.1665	4.958	71.12	71.13	.5349	.5274	[illegible]

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H_o'	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.3900	.3955	2.485	.9862	5.957	6.040	.9739	.1656	4.970	71.97	71.98	.5345	.5271	5.074
.3910	.3964	2.491	.9864	5.993	6.076	.9741	.1646	4.982	72.85	72.86	.5342	.5269	5.072
.3920	.3974	2.497	.9865	6.029	6.112	.9743	.1636	4.993	73.72	73.72	.5339	.5267	5.071
.3930	.3983	2.503	.9867	6.066	6.148	.9745	.1627	5.005	74.58	74.59	.5336	.5265	5.069
.3940	.3993	2.509	.9869	6.103	6.185	.9748	.1617	5.017	75.48	75.49	.5332	.5262	5.067
.3950	.4002	2.515	.9870	6.140	6.221	.9750	.1608	5.029	76.40	76.40	.5329	.5260	5.066
.3960	.4012	2.521	.9872	6.177	6.258	.9752	.1598	5.041	77.31	77.32	.5326	.5258	5.064
.3970	.4021	2.527	.9873	6.215	6.295	.9754	.1589	5.053	78.24	78.24	.5323	.5255	5.063
.3980	.4031	2.532	.9874	6.252	6.332	.9756	.1579	5.065	79.19	79.19	.5320	.5253	5.062
.3990	.4040	2.538	.9876	6.290	6.369	.9758	.1570	5.077	80.13	80.13	.5317	.5251	5.060
.4000	.4050	2.544	.9877	6.329	6.407	.9761	.1561	5.089	81.12	81.12	.5314	.5248	5.058
.4010	.4059	2.550	.9879	6.367	6.445	.9763	.1552	5.101	82.07	82.08	.5311	.5246	5.056
.4020	.4069	2.556	.9880	6.406	6.483	.9765	.1542	5.113	83.06	83.06	.5308	.5244	5.055
.4030	.4078	2.562	.9882	6.444	6.521	.9766	.1533	5.125	84.07	84.07	.5305	.5242	5.053
.4040	.4088	2.568	.9883	6.484	6.561	.9768	.1524	5.137	85.11	85.12	.5302	.5240	5.052
.4050	.4098	2.575	.9885	6.525	6.601	.9770	.1515	5.149	86.14	86.14	.5299	.5238	5.050
.4060	.4107	2.581	.9886	6.564	6.640	.9772	.1506	5.161	87.17	87.17	.5296	.5236	5.049
.4070	.4116	2.586	.9887	6.603	6.679	.9774	.1497	5.173	88.19	88.20	.5293	.5234	5.048
.4080	.4126	2.592	.9889	6.644	6.718	.9776	.1488	5.185	89.28	89.28	.5290	.5232	5.046
.4090	.4136	2.598	.9890	6.684	6.758	.9778	.1480	5.197	90.38	90.39	.5287	.5229	5.045
.4100	.4145	2.604	.9891	6.725	6.799	.9780	.1471	5.209	91.44	91.44	.5285	.5227	5.044
.4110	.4155	2.610	.9892	6.766	6.839	.9782	.1462	5.221	92.54	92.55	.5282	.5225	5.043
.4120	.4164	2.616	.9894	6.806	6.879	.9784	.1454	5.233	93.67	93.67	.5279	.5223	5.041
.4130	.4174	2.623	.9895	6.849	6.921	.9786	.1445	5.245	94.83	94.83	.5277	.5221	5.040
.4140	.4183	2.629	.9896	6.890	6.963	.9788	.1436	5.257	95.95	95.96	.5274	.5219	5.039
.4150	.4193	2.635	.9898	6.932	7.004	.9790	.1428	5.269	97.13	97.13	.5271	.5217	5.037
.4160	.4203	2.641	.9899	6.974	7.046	.9792	.1419	5.281	98.29	98.30	.5269	.5215	5.036
.4170	.4212	2.647	.9900	7.018	7.088	.9794	.1411	5.294	99.52	99.52	.5266	.5213	5.035
.4180	.4222	2.653	.9901	7.060	7.130	.9795	.1403	5.305	100.7	100.7	.5263	.5211	5.034
.4190	.4231	2.659	.9902	7.102	7.173	.9797	.1394	5.317	101.9	101.9	.5261	.5209	5.033
.4200	.4241	2.665	.9904	7.146	7.215	.9798	.1386	5.329	103.1	103.1	.5258	.5208	5.031
.4210	.4251	2.671	.9905	7.190	7.259	.9800	.1378	5.341	104.4	104.4	.5256	.5206	5.030
.4220	.4260	2.677	.9906	7.234	7.303	.9802	.1369	5.353	105.7	105.7	.5253	.5204	5.029
.4230	.4270	2.683	.9907	7.279	7.349	.9804	.1361	5.366	107.0	107.0	.5251	.5202	5.028
.4240	.4280	2.689	.9908	7.325	7.392	.9806	.1353	5.378	108.3	108.3	.5248	.5200	5.027
.4250	.4289	2.695	.9909	7.371	7.438	.9808	.1345	5.390	109.7	109.7	.5246	.5198	5.026
.4260	.4298	2.701	.9910	7.412	7.479	.9810	.1337	5.402	110.9	110.9	.5244	.5196	5.025
.4270	.4308	2.707	.9911	7.457	7.524	.9811	.1329	5.414	112.2	112.2	.5241	.5195	5.024
.4280	.4318	2.713	.9912	7.503	7.570	.9812	.1321	5.426	113.6	113.6	.5239	.5193	5.023
.4290	.4328	2.719	.9913	7.550	7.616	.9814	.1313	5.438	115.0	115.0	.5237	.5191	5.022
.4300	.4337	2.725	.9914	7.595	7.661	.9816	.1305	5.450	116.4	116.4	.5234	.5189	5.021
.4310	.4347	2.731	.9915	7.642	7.707	.9818	.1298	5.462	117.8	117.8	.5232	.5187	5.020
.4320	.4356	2.737	.9916	7.688	7.753	.9819	.1290	5.474	119.2	119.3	.5230	.5186	5.019
.4330	.4366	2.743	.9917	7.735	7.800	.9821	.1282	5.486	120.7	120.7	.5227	.5184	5.018
.4340	.4376	2.749	.9918	7.783	7.847	.9823	.1274	5.499	122.2	122.2	.5225	.5182	5.017
.4350	.4385	2.755	.9919	7.831	7.895	.9824	.1267	5.511	123.7	123.7	.5223	.5181	5.016
.4360	.4395	2.762	.9920	7.880	7.943	.9826	.1259	5.523	125.2	125.2	.5221	.5179	5.015
.4370	.4405	2.768	.9921	7.922	7.991	.9828	.1251	5.535	126.7	126.7	.5218	.5177	5.014
.4380	.4414	2.774	.9922	7.975	8.035	.9829	.1244	5.547	128.3	128.3	.5216	.5176	5.013
.4390	.4424	2.780	.9923	8.026	8.088	.9830	.1236	5.560	129.9	129.9	.5214	.5174	5.012
.4400	.4434	2.786	.9924	8.075	8.136	.9832	.1229	5.572	131.4	131.4	.5212	.5172	5.011
.4410	.4443	2.792	.9925	8.124	8.185	.9833	.1222	5.584	133.0	133.0	.5210	.5171	5.010
.4420	.4453	2.798	.9926	8.175	8.236	.9835	.1214	5.596	134.7	134.7	.5208	.5169	5.009
.4430	.4463	2.804	.9927	8.228	8.285	.9836	.1207	5.608	136.3	136.3	.5206	.5168	5.008
.4440	.4472	2.810	.9928	8.274	8.334	.9838	.1200	5.620	137.9	137.9	.5204	.5166	5.007
.4450	.4482	2.816	.9929	8.326	8.387	.9839	.1192	5.632	139.6	139.7	.5202	.5165	5.006
.4460	.4492	2.822	.9930	8.379	8.438	.9841	.1185	5.644	141.4	141.4	.5200	.5163	5.005
.4470	.4501	2.828	.9930	8.427	8.486	.9843	.1178	5.657	143.1	143.1	.5198	.5161	5.005
.4480	.4511	2.834	.9931	8.481	8.540	.9844	.1171	5.669	144.3	144.8	.5196	.5160	5.004
.4490	.4521	2.840	.9932	8.532	8.590	.9846	.1164	5.681	146.6	146.6	.5194	.5158	5.003

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH 2 d/L	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.4500	.4531	2.847	.9933	8.585	8.643	.9847	.1157	5.693	148.4	148.4	.5192	.5157	5.002
.4510	.4540	2.853	.9934	8.638	8.695	.9848	.1150	5.705	150.2	150.2	.5190	.5156	5.001
.4520	.4550	2.859	.9935	8.693	8.750	.9849	.1143	5.717	152.1	152.1	.5188	.5154	5.000
.4530	.4560	2.865	.9935	8.747	8.804	.9851	.1136	5.730	154.0	154.0	.5186	.5152	5.000
.4540	.4569	2.871	.9936	8.797	8.854	.9852	.1129	5.742	155.9	155.9	.5184	.5151	4.999
.4550	.4579	2.877	.9937	8.853	8.910	.9853	.1122	5.754	157.7	157.7	.5182	.5150	4.998
.4560	.4589	2.883	.9938	8.910	8.965	.9855	.1115	5.766	159.7	159.7	.5181	.5148	4.997
.4570	.4599	2.890	.9938	8.965	9.021	.9857	.1109	5.779	161.7	161.7	.5179	.5146	4.997
.4580	.4608	2.896	.9939	9.016	9.072	.9858	.1102	5.791	163.6	163.6	.5177	.5145	4.996
.4590	.4618	2.902	.9940	9.074	9.129	.9859	.1095	5.803	165.6	165.6	.5175	.5144	4.995
.4600	.4628	2.908	.9941	9.132	9.186	.9860	.1089	5.815	167.7	167.7	.5173	.5143	4.994
.4610	.4637	2.914	.9941	9.183	9.238	.9862	.1083	5.827	169.7	169.7	.5172	.5141	4.994
.4620	.4647	2.920	.9942	9.242	9.296	.9863	.1076	5.840	171.8	171.8	.5170	.5140	4.993
.4630	.4657	2.926	.9943	9.301	9.354	.9864	.1069	5.852	173.9	173.9	.5168	.5139	4.992
.4640	.4666	2.932	.9944	9.353	9.406	.9865	.1063	5.864	176.0	176.0	.5167	.5138	4.991
.4650	.4676	2.938	.9944	9.413	9.466	.9867	.1056	5.876	178.2	178.2	.5165	.5136	4.991
.4660	.4686	2.944	.9945	9.472	9.525	.9868	.1050	5.888	180.4	180.4	.5163	.5135	4.990
.4670	.4695	2.951	.9946	9.533	9.585	.9869	.1043	5.900	182.6	182.6	.5162	.5134	4.989
.4680	.4705	2.957	.9946	9.586	9.638	.9871	.1037	5.912	184.8	184.8	.5160	.5132	4.989
.4690	.4715	2.963	.9947	9.647	9.699	.9872	.1031	5.925	187.2	187.2	.5158	.5131	4.988
.4700	.4725	2.969	.9947	9.709	9.760	.9873	.1025	5.937	189.5	189.5	.5157	.5129	4.988
.4710	.4735	2.975	.9948	9.770	9.821	.9874	.1018	5.949	191.8	191.8	.5155	.5128	4.987
.4720	.4744	2.981	.9949	9.826	9.877	.9875	.1012	5.962	194.2	194.2	.5154	.5127	4.986
.4730	.4754	2.987	.9949	9.888	9.938	.9876	.1006	5.974	196.5	196.5	.5152	.5126	4.986
.4740	.4764	2.993	.9950	9.951	10.00	.9877	.1000	5.986	199.0	199.0	.5150	.5125	4.985
.4750	.4774	2.999	.9951	10.01	10.07	.9878	.09942	5.999	201.4	201.4	.5149	.5124	4.984
.4760	.4783	3.005	.9951	10.07	10.12	.9880	.09882	6.011	203.9	203.9	.5147	.5122	4.984
.4770	.4793	3.012	.9952	10.13	10.18	.9881	.09820	6.023	206.5	206.5	.5146	.5121	4.983
.4780	.4803	3.018	.9952	10.20	10.25	.9882	.09759	6.036	209.0	209.0	.5144	.5120	4.983
.4790	.4813	3.024	.9953	10.26	10.31	.9883	.09698	6.048	211.7	211.7	.5143	.5119	4.982
.4800	.4822	3.030	.9953	10.32	10.37	.9885	.09641	6.060	214.2	214.2	.5142	.5117	4.982
.4810	.4832	3.036	.9954	10.39	10.43	.9886	.09583	6.072	216.8	216.8	.5140	.5116	4.981
.4820	.4842	3.042	.9955	10.45	10.50	.9887	.09523	6.085	219.5	219.5	.5139	.5115	4.980
.4830	.4852	3.049	.9955	10.52	10.57	.9888	.09464	6.097	222.2	222.2	.5137	.5114	4.980
.4840	.4862	3.055	.9956	10.59	10.63	.9889	.09405	6.109	225.0	225.0	.5136	.5113	4.979
.4850	.4871	3.061	.9956	10.65	10.69	.9890	.09352	6.121	228.3	228.3	.5134	.5112	4.979
.4860	.4881	3.067	.9957	10.71	10.76	.9891	.09294	6.134	230.6	230.6	.5133	.5111	4.978
.4870	.4891	3.073	.9957	10.78	10.83	.9892	.09236	6.146	233.5	233.5	.5132	.5110	4.978
.4880	.4901	3.079	.9958	10.85	10.90	.9893	.09178	6.159	236.4	236.4	.5130	.5109	4.977
.4890	.4911	3.086	.9958	10.92	10.96	.9895	.09121	6.171	239.6	239.6	.5129	.5107	4.977
.4900	.4920	3.092	.9959	10.99	11.03	.9896	.09064	6.183	242.3	242.3	.5128	.5106	4.976
.4910	.4930	3.098	.9959	11.05	11.09	.9897	.09010	6.195	245.2	245.2	.5126	.5105	4.976
.4920	.4940	3.104	.9960	11.12	11.16	.9898	.08956	6.208	248.3	248.3	.5125	.5104	4.975
.4930	.4950	3.110	.9960	11.19	11.24	.9899	.08901	6.220	251.3	251.3	.5124	.5103	4.975
.4940	.4960	3.117	.9961	11.26	11.31	.9899	.08845	6.232	254.5	254.5	.5122	.5102	4.974
.4950	.4969	3.122	.9961	11.32	11.37	.9900	.08793	6.245	257.6	257.6	.5121	.5101	4.974
.4960	.4979	3.128	.9962	11.40	11.44	.9901	.08741	6.257	260.8	260.8	.5120	.5100	4.973
.4970	.4989	3.135	.9962	11.47	11.51	.9902	.08691	6.269	264.0	264.0	.5119	.5099	4.973
.4980	.4999	3.141	.9963	11.54	11.59	.9903	.08637	6.282	267.3	267.3	.5118	.5098	4.972
.4990	.5009	3.147	.9963	11.61	11.65	.9904	.08584	6.294	270.6	270.6	.5116	.5097	4.972
.5000	.5018	3.153	.9964	11.68	11.72	.9905	.08530	6.306	274.0	274.0	.5115	.5096	4.971
.5010	.5028	3.159	.9964	11.75	11.80	.9906	.08477	6.319	277.5	277.5	.5114	.5095	4.971
.5020	.5038	3.166	.9964	11.83	11.87	.9907	.08424	6.331	280.8	280.8	.5113	.5094	4.971
.5030	.5048	3.172	.9965	11.91	11.95	.9908	.08371	6.343	284.3	284.3	.5112	.5093	4.970
.5040	.5058	3.178	.9965	11.98	12.02	.9909	.08320	6.356	287.9	287.9	.5110	.5092	4.970
.5050	.5067	3.184	.9966	12.05	12.09	.9909	.08270	6.368	291.4	291.4	.5109	.5092	4.969
.5060	.5077	3.190	.9966	12.12	12.16	.9910	.08220	6.380	295.0	295.0	.5108	.5091	4.969
.5070	.5087	3.196	.9967	12.20	12.24	.9911	.08169	6.393	298.7	298.7	.5107	.5090	4.968
.5080	.5097	3.203	.9967	12.28	12.32	.9912	.08119	6.405	302.4	302.4	.5106	.5089	4.968
.5090	.5107	3.209	.9968	12.35	12.39	.9913	.08068	6.417	306.2	306.2	.5105	.5088	4.967

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.5100	.5117	3.215	.9968	12.43	12.47	.9914	.08022	6.430	310.0	310.0	.5104	.5087	4.967
.5110	.5126	3.221	.9968	12.50	12.54	.9915	.07972	6.442	313.8	313.8	.5103	.5086	4.967
.5120	.5136	3.227	.9969	12.58	12.62	.9915	.07922	6.454	317.7	317.7	.5102	.5086	4.966
.5130	.5146	3.233	.9969	12.66	12.70	.9916	.07873	6.467	321.7	321.7	.5101	.5085	4.966
.5140	.5156	3.240	.9970	12.74	12.78	.9917	.07824	6.479	325.7	325.7	.5100	.5084	4.965
.5150	.5166	3.246	.9970	12.82	12.86	.9918	.07776	6.491	329.7	329.7	.5098	.5083	4.965
.5160	.5176	3.252	.9970	12.90	12.94	.9919	.07729	6.504	333.8	333.8	.5097	.5082	4.965
.5170	.5185	3.258	.9971	12.98	13.02	.9919	.07682	6.516	337.9	337.9	.5096	.5082	4.964
.5180	.5195	3.264	.9971	13.06	13.10	.9920	.07634	6.529	342.2	342.2	.5095	.5081	4.964
.5190	.5205	3.270	.9971	13.14	13.18	.9921	.07587	6.541	346.4	346.4	.5094	.5080	4.964
.5200	.5215	3.277	.9972	13.22	13.26	.9922	.07540	6.553	350.7	350.7	.5093	.5079	4.963
.5210	.5225	3.283	.9972	13.31	13.35	.9923	.07494	6.566	355.1	355.1	.5092	.5078	4.963
.5220	.5235	3.289	.9972	13.39	13.43	.9924	.07449	6.578	359.6	359.6	.5092	.5077	4.963
.5230	.5244	3.295	.9973	13.47	13.51	.9924	.07404	6.590	364.0	364.0	.5091	.5077	4.962
.5240	.5254	3.301	.9973	13.55	13.59	.9925	.07358	6.603	368.5	368.5	.5090	.5076	4.962
.5250	.5264	3.308	.9973	13.64	13.68	.9926	.07312	6.615	373.1	373.1	.5089	.5075	4.962
.5260	.5274	3.314	.9974	13.73	13.76	.9927	.07266	6.628	377.8	377.8	.5088	.5074	4.961
.5270	.5284	3.320	.9974	13.81	13.85	.9927	.07221	6.640	382.5	382.5	.5087	.5074	4.961
.5280	.5294	3.326	.9974	13.90	13.94	.9928	.07177	6.652	387.3	387.3	.5086	.5073	4.961
.5290	.5304	3.333	.9975	13.99	14.02	.9929	.07134	6.665	392.2	392.2	.5085	.5072	4.960
.5300	.5314	3.339	.9975	14.07	14.10	.9930	.07091	6.677	397.0	397.0	.5084	.5071	4.960
.5310	.5323	3.345	.9975	14.16	14.19	.9931	.07047	6.690	402.0	402.0	.5083	.5070	4.960
.5320	.5333	3.351	.9976	14.25	14.28	.9931	.07003	6.702	406.9	406.9	.5082	.5070	4.959
.5330	.5343	3.357	.9976	14.34	14.37	.9932	.06959	6.714	412.0	412.0	.5082	.5069	4.959
.5340	.5353	3.363	.9976	14.43	14.46	.9933	.06915	6.727	417.2	417.2	.5081	.5068	4.959
.5350	.5363	3.370	.9976	14.52	14.55	.9933	.06872	6.739	422.4	422.4	.5080	.5068	4.959
.5360	.5373	3.376	.9977	14.61	14.64	.9934	.06829	6.752	427.7	427.7	.5079	.5067	4.958
.5370	.5383	3.382	.9977	14.70	14.73	.9935	.06787	6.764	433.1	433.1	.5078	.5066	4.958
.5380	.5393	3.388	.9977	14.79	14.82	.9935	.06746	6.776	438.5	438.5	.5077	.5066	4.958
.5390	.5402	3.394	.9977	14.88	14.91	.9936	.06705	6.789	444.0	444.0	.5077	.5065	4.958
.5400	.5412	3.401	.9978	14.97	15.01	.9936	.06664	6.801	449.5	449.5	.5076	.5065	4.957
.5410	.5422	3.407	.9978	15.07	15.10	.9937	.06623	6.814	455.1	455.1	.5075	.5064	4.957
.5420	.5432	3.413	.9978	15.16	15.19	.9938	.06582	6.826	460.7	460.7	.5074	.5063	4.957
.5430	.5442	3.419	.9979	15.25	15.29	.9938	.06542	6.838	466.4	466.4	.5073	.5063	4.956
.5440	.5452	3.426	.9979	15.35	15.38	.9939	.06501	6.851	472.2	472.2	.5073	.5062	4.956
.5450	.5461	3.432	.9979	15.45	15.48	.9940	.06461	6.863	478.1	478.1	.5072	.5061	4.956
.5460	.5471	3.438	.9979	15.54	15.58	.9941	.06420	6.876	484.3	484.3	.5071	.5060	4.956
.5470	.5481	3.444	.9980	15.64	15.67	.9941	.06380	6.888	490.3	490.3	.5070	.5060	4.955
.5480	.5491	3.450	.9980	15.74	15.77	.9942	.06341	6.901	496.4	496.4	.5070	.5059	4.955
.5490	.5501	3.456	.9980	15.84	15.87	.9942	.06302	6.913	502.5	502.5	.5069	.5059	4.955
.5500	.5511	3.463	.9980	15.94	15.97	.9942	.06263	6.925	508.7	508.7	.5068	.5058	4.955
.5510	.5521	3.469	.9981	16.04	16.07	.9942	.06224	6.937	515.0	515.0	.5067	.5058	4.954
.5520	.5531	3.475	.9981	16.14	16.17	.9943	.06186	6.950	521.6	521.6	.5067	.5057	4.954
.5530	.5541	3.481	.9981	16.24	16.27	.9944	.06148	6.962	528.1	528.1	.5066	.5056	4.954
.5540	.5551	3.488	.9981	16.34	16.37	.9944	.06110	6.975	534.8	534.8	.5065	.5056	4.954
.5550	.5560	3.494	.9982	16.44	16.47	.9945	.06073	6.987	541.4	541.4	.5065	.5056	4.953
.5560	.5570	3.500	.9982	16.54	16.57	.9945	.06035	7.000	548.1	548.1	.5064	.5055	4.953
.5570	.5580	3.506	.9982	16.65	16.68	.9946	.05997	7.012	554.9	554.9	.5063	.5054	4.953
.5580	.5590	3.512	.9982	16.75	16.78	.9947	.05960	7.025	562.0	562.0	.5063	.5053	4.953
.5590	.5600	3.519	.9982	16.85	16.88	.9947	.05923	7.037	569.1	569.1	.5062	.5053	4.953
.5600	.5610	3.525	.9983	16.96	16.99	.9947	.05887	7.050	576.1	576.1	.5061	.5053	4.952
.5610	.5620	3.531	.9983	17.06	17.09	.9948	.05850	7.062	583.3	583.3	.5061	.5052	4.952
.5620	.5630	3.537	.9983	17.17	17.20	.9949	.05814	7.074	590.7	590.7	.5060	.5051	4.952
.5630	.5640	3.543	.9983	17.28	17.31	.9949	.05778	7.087	598.0	598.0	.5059	.5051	4.952
.5640	.5649	3.550	.9984	17.38	17.41	.9950	.05743	7.099	605.0	605.0	.5059	.5050	4.951
.5650	.5659	3.556	.9984	17.49	17.52	.9950	.05707	7.112	613.2	613.2	.5058	.5050	4.951
.5660	.5669	3.562	.9984	17.60	17.63	.9951	.05672	7.124	620.8	620.8	.5057	.5049	4.951
.5670	.5679	3.568	.9984	17.71	17.74	.9951	.05637	7.136	628.5	628.5	.5057	.5049	4.951
.5680	.5689	3.575	.9984	17.82	17.85	.9952	.05602	7.149	636.4	636.4	.5056	.5048	4.951
.5690	.5699	3.581	.9985	17.94	17.97	.9952	.05567	7.161	644.3	644.3	.5056	.5048	4.950

Table C-1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.5700	.5709	3.587	.9985	18.05	18.08	.9953	.05532	7.174	652.4	652.4	.5055	.5047	4.950
.5710	.5719	3.593	.9985	18.16	18.19	.9953	.05497	7.186	660.5	660.5	.5054	.5047	4.950
.5720	.5729	3.600	.9985	18.28	18.31	.9954	.05463	7.199	668.8	668.8	.5054	.5046	4.950
.5730	.5738	3.606	.9985	18.39	18.42	.9954	.05430	7.211	677.2	677.2	.5053	.5046	4.950
.5740	.5748	3.612	.9985	18.50	18.53	.9955	.05396	7.224	685.6	685.6	.5053	.5045	4.950
.5750	.5758	3.618	.9986	18.62	18.64	.9955	.05363	7.236	694.3	694.3	.5052	.5045	4.949
.5760	.5768	3.624	.9986	18.73	18.76	.9956	.05330	7.249	703.2	703.2	.5052	.5044	4.949
.5770	.5778	3.630	.9986	18.85	18.88	.9956	.05297	7.261	711.9	711.9	.5051	.5044	4.949
.5780	.5788	3.637	.9986	18.97	19.00	.9957	.05264	7.274	720.8	720.8	.5051	.5043	4.949
.5790	.5798	3.643	.9986	19.09	19.12	.9957	.05231	7.286	729.9	729.9	.5050	.5043	4.949
.5800	.5808	3.649	.9987	19.21	19.24	.9957	.05198	7.298	739.0	739.0	.5049	.5043	4.948
.5810	.5818	3.656	.9987	19.33	19.36	.9958	.05166	7.311	748.1	748.1	.5049	.5042	4.948
.5820	.5828	3.662	.9987	19.45	19.48	.9958	.05134	7.323	757.5	757.5	.5048	.5042	4.948
.5830	.5838	3.668	.9987	19.58	19.60	.9959	.05102	7.336	767.0	767.0	.5048	.5041	4.948
.5840	.5848	3.674	.9987	19.70	19.73	.9959	.05070	7.348	776.7	776.7	.5047	.5041	4.948
.5850	.5858	3.680	.9987	19.81	19.84	.9960	.05040	7.361	786.5	786.5	.5047	.5040	4.948
.5860	.5867	3.686	.9987	19.94	19.96	.9960	.05009	7.373	796.4	796.4	.5046	.5040	4.948
.5870	.5877	3.693	.9988	20.06	20.09	.9960	.04978	7.386	806.5	806.5	.5046	.5040	4.947
.5880	.5887	3.699	.9988	20.19	20.21	.9961	.04947	7.398	816.5	816.5	.5045	.5039	4.947
.5890	.5897	3.705	.9988	20.32	20.34	.9961	.04916	7.411	826.7	826.7	.5045	.5039	4.947
.5900	.5907	3.712	.9988	20.45	20.47	.9962	.04885	7.423	837.1	837.1	.5044	.5038	4.947
.5910	.5917	3.718	.9988	20.57	20.60	.9962	.04855	7.436	847.6	847.6	.5044	.5038	4.947
.5920	.5927	3.724	.9988	20.70	20.73	.9963	.04824	7.448	858.2	858.2	.5043	.5037	4.947
.5930	.5937	3.730	.9989	20.83	20.86	.9963	.04794	7.460	868.9	868.9	.5043	.5037	4.946
.5940	.5947	3.737	.9989	20.97	20.99	.9963	.04764	7.473	879.8	879.8	.5043	.5037	4.946
.5950	.5957	3.743	.9989	21.10	21.12	.9964	.04735	7.485	890.8	890.8	.5042	.5036	4.946
.5960	.5967	3.749	.9989	21.23	21.25	.9964	.04706	7.498	901.9	901.9	.5042	.5036	4.946
.5970	.5977	3.755	.9989	21.35	21.37	.9964	.04677	7.510	913.4	913.4	.5041	.5036	4.946
.5980	.5987	3.761	.9989	21.49	21.51	.9965	.04648	7.523	925.0	925.0	.5041	.5035	4.946
.5990	.5996	3.767	.9989	21.62	21.64	.9965	.04619	7.535	936.5	936.5	.5040	.5035	4.946
.6000	.6006	3.774	.9990	21.76	21.78	.9965	.04591	7.548	948.1	948.1	.5040	.5035	4.945
.6100	.6106	3.836	.9991	23.17	23.19	.9969	.04313	7.673	1,074	1,074	.5036	.5031	4.944
.6200	.6205	3.899	.9992	24.66	24.68	.9972	.04052	7.798	1,217	1,217	.5032	.5028	4.943
.6300	.6305	3.961	.9993	26.25	26.27	.9975	.03806	7.923	1,379	1,379	.5029	.5025	4.942
.6400	.6404	4.024	.9994	27.95	27.97	.9977	.03576	8.048	1,527	1,527	.5026	.5023	4.941
.6500	.6504	4.086	.9994	29.75	29.77	.9980	.03359	8.173	1,771	1,771	.5023	.5020	4.940
.6600	.6603	4.149	.9995	31.68	31.69	.9982	.03155	8.298	2,008	2,008	.5021	.5018	4.940
.6700	.6703	4.212	.9996	33.73	33.74	.9983	.02964	8.423	2,275	2,275	.5019	.5017	4.939
.6800	.6803	4.274	.9996	35.90	35.92	.9985	.02784	8.548	2,579	2,579	.5017	.5015	4.939
.6900	.6902	4.337	.9997	38.23	38.24	.9987	.02615	8.674	2,923	2,923	.5015	.5013	4.938
.7000	.7002	4.400	.9997	40.71	40.72	.9988	.02456	8.799	3,314	3,314	.5013	.5012	4.938
.7100	.7102	4.462	.9997	43.34	43.35	.9989	.02307	8.925	3,757	3,757	.5012	.5011	4.937
.7200	.7202	4.525	.9998	46.14	46.15	.9990	.02167	9.050	4,258	4,258	.5011	.5010	4.937
.7300	.7302	4.588	.9998	49.13	49.14	.9991	.02035	9.175	4,828	4.828	.5010	.5009	4.937
.7400	.7401	4.650	.9998	52.31	52.32	.9992	.01911	9.301	5,473	5,473	.5009	.5008	4.937
.7500	.7501	4.713	.9998	55.70	55.71	.9993	.01795	9.426	6,204	6,204	.5008	.5007	4.936
.7600	.7601	4.776	.9999	59.31	59.31	.9994	.01686	9.552	7,034	7,034	.5007	.5006	4.936
.7700	.7701	4.839	.9999	63.15	63.16	.9995	.01583	9.677	7,976	7,976	.5006	.5005	4.936
.7800	.7801	4.902	.9999	67.24	67.25	.9996	.01487	9.803	9,042	9,042	.5005	.5004	4.936
.7900	.7901	4.964	.9999	71.60	71.60	.9996	.01397	9.929	10,250	10,250	.5005	.5004	4.936
.8000	.8001	5.027	.9999	76.24	76.24	.9996	.01312	10.05	11,620	11,620	.5004	.5004	4.936
.8100	.8101	5.090	.9999	81.18	81.19	.9996	.01232	10.18	13,180	13,180	.5004	.5004	4.936
.8200	.8201	5.153	.9999	86.44	86.44	.9997	.01157	10.31	14,940	14,940	.5003	.5003	4.935
.8300	.8301	5.215	.9999	92.04	92.05	.9997	.01086	10.43	17,340	17,340	.5003	.5003	4.935
.8400	.8400	5.278	1.000	98.00	98.01	.9997	.01020	10.56	19,210	19,210	.5003	.5003	4.935
.8500	.8500	5.341	1.000	104.4	104.4	.9998	.009582	10.68	21,780	21,780	.5002	.5002	4.935
.8600	.8600	5.404	1.000	111.1	111.1	.9998	.009000	10.81	24,690	24,690	.5002	.5002	4.935
.8700	.8700	5.467	1.000	118.3	118.3	.9998	.008451	10.93	28,000	28,000	.5002	.5002	4.935
.8800	.8800	5.529	1.000	126.0	126.0	.9998	.007934	11.06	31,750	31,750	.5002	.5002	4.935
.8900	.8900	5.592	1.000	134.2	134.2	.9998	.007454	11.18	36,000	36,000	.5002	.5002	4.935

Table C-1. Concluded.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.9000	.9000	5.655	1.000	142.9	142.9	.9999	.007000	11.31	40,810	40,810	.5001	.5001	4.935
.9100	.9100	5.718	1.000	152.1	152.1	.9999	.006574	11.44	46,280	46,280	.5001	.5001	4.935
.9200	.9200	5.781	1.000	162.0	162.0	.9999	.006173	11.56	52,470	52,470	.5001	.5001	4.935
.9300	.9300	5.844	1.000	172.5	172.5	.9999	.005797	11.69	59,500	59,500	.5001	.5001	4.935
.9400	.9400	5.906	1.000	183.7	183.7	.9999	.005445	11.81	67,470	67,470	.5001	.5001	4.935
.9500	.9500	5.969	1.000	195.6	195.6	.9999	.005114	11.94	76,490	76,490	.5001	.5001	4.935
.9600	.9600	6.032	1.000	208.2	208.2	.9999	.004802	12.06	86,740	86,740	.5001	.5001	4.935
.9700	.9700	6.095	1.000	221.7	221.7	.9999	.004510	12.19	98,340	98,340	.5001	.5001	4.935
.9800	.9800	6.158	1.000	236.1	236.1	.9999	.004235	12.32	111,500	111,500	.5001	.5001	4.935
.9900	.9900	6.220	1.000	251.4	251.4	1.000	.003977	12.44	126,500	126,500	.5000	.5000	4.935
1.000	1.000	6.283	1.000	267.7	267.7	1.000	.003735	12,57	143,400	143,400	.5000	.5000	4.935

after Wiegel, R. L., "Oscillatory Waves," U.S. Army, Beach Erosion Board, Bulletin, Special Issue No. 1, July 1948.

APPENDIX C

CALCULATION RESULTS FOR WAVELENGTH WITH RESPECT TO THE WAVE PERIOD

Water depth, d (m)	Frequency, f (rpm)	Wave period, T (s)	Deepwater wavelength, L_o (m)	d/L_o	d/L	Wavelength, L (m)
mea.		mea.	calc.	calc.	calc.	calc.
0.2	55.33	0.81	1.02	0.196	0.558	0.36
0.2	51.70	0.87	1.18	0.169	0.427	0.47
0.2	48.51	0.93	1.35	0.148	0.344	0.58
0.2	45.90	0.99	1.52	0.132	0.289	0.69
0.2	43.54	1.04	1.70	0.118	0.250	0.80
0.2	41.50	1.10	1.88	0.106	0.221	0.90
0.2	39.59	1.15	2.08	0.096	0.200	1.00
0.2	37.91	1.21	2.28	0.088	0.182	1.10
0.2	36.40	1.26	2.49	0.080	0.168	1.19
0.2	35.03	1.31	2.70	0.074	0.156	1.28
0.2	33.78	1.37	2.91	0.069	0.146	1.37
0.3	55.33	0.81	1.02	0.293	0.836	0.36
0.3	51.70	0.87	1.18	0.254	0.635	0.47
0.3	48.51	0.93	1.35	0.222	0.505	0.59
0.3	45.90	0.99	1.52	0.197	0.416	0.72
0.3	43.54	1.04	1.70	0.176	0.352	0.85
0.3	41.50	1.10	1.88	0.159	0.306	0.98
0.3	39.59	1.15	2.08	0.144	0.271	1.11
0.3	37.91	1.21	2.28	0.132	0.244	1.23
0.3	36.40	1.26	2.49	0.121	0.223	1.35
0.3	35.03	1.31	2.70	0.111	0.205	1.46
0.3	33.78	1.37	2.91	0.103	0.191	1.57

APPENDIX D

SUMMARY OF RESULTS AND CALCULATIONS
(VI PARTS)

Part I

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	D (m)	d (m)	**Anchoring**	f (rpm)	T (s)	L_o (m)	d/L_o	d/L*	L (m)	H_i (cm)	H_t (cm)	$C_T = H_t/H_i$	H_i/D	$2\pi L/gT^2 = L/L_o$	H_i/L	B/L	D/d	H_i/d
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M1-20-P-01		0.60	0.2	PILE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	4.50	0.658	0.114	0.350	0.191	0.558	3.00	0.342
M1-20-P-02		0.60	0.2	PILE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	3.50	0.477	0.122	0.396	0.157	0.427	3.00	0.367
M1-20-P-03		0.60	0.2	PILE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	4.00	0.533	0.125	0.430	0.129	0.344	3.00	0.375
M1-20-P-04		0.60	0.2	PILE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	4.50	0.575	0.131	0.455	0.113	0.289	3.00	0.392
M1-20-P-05		0.60	0.2	PILE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	4.25	0.728	0.097	0.470	0.073	0.250	3.00	0.292
M1-20-P-06	M1	0.60	0.2	PILE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	3.50	0.583	0.100	0.480	0.066	0.221	3.00	0.300
M1-20-P-07		0.60	0.2	PILE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	4.75	0.731	0.108	0.482	0.065	0.200	3.00	0.325
M1-20-P-08		0.60	0.2	PILE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	3.08	0.560	0.092	0.483	0.050	0.182	3.00	0.275
M1-20-P-09		0.60	0.2	PILE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	3.50	0.700	0.083	0.479	0.042	0.168	3.00	0.250
M1-20-P-10		0.60	0.2	PILE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	3.75	0.833	0.075	0.475	0.035	0.156	3.00	0.225
M1-20-P-11		0.60	0.2	PILE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	4.58	0.983	0.078	0.469	0.034	0.146	3.00	0.233
M1-30-P-01		0.60	0.3	PILE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	9.50	1.076	0.147	0.351	0.246	0.558	2.00	0.294
M1-30-P-02		0.60	0.3	PILE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	8.00	0.872	0.153	0.400	0.194	0.424	2.00	0.306
M1-30-P-03		0.60	0.3	PILE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	5.00	0.500	0.167	0.440	0.168	0.337	2.00	0.333
M1-30-P-04		0.60	0.3	PILE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	7.00	0.676	0.173	0.475	0.143	0.277	2.00	0.345
M1-30-P-05		0.60	0.3	PILE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	8.00	0.873	0.153	0.501	0.108	0.235	2.00	0.305
M1-30-P-06	M1	0.60	0.3	PILE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	5.00	0.577	0.144	0.520	0.088	0.204	2.00	0.289
M1-30-P-07		0.60	0.3	PILE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	9.50	1.294	0.122	0.531	0.066	0.181	2.00	0.245
M1-30-P-08		0.60	0.3	PILE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	7.00	0.763	0.153	0.540	0.075	0.163	2.00	0.306
M1-30-P-09		0.60	0.3	PILE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	5.00	0.769	0.108	0.541	0.048	0.149	2.00	0.217
M1-30-P-10		0.60	0.3	PILE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	4.00	0.749	0.089	0.542	0.037	0.137	2.00	0.178
M1-30-P-11		0.60	0.3	PILE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	3.50	0.553	0.106	0.539	0.040	0.127	2.00	0.211

Part II

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**d/L_o**	**d/L***	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$2\pi L/gT^2 = L/L_o$**	**H_i/L**	**B/L**	**D/d**	**H_i/d**
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M2-20-P-01		0.69	0.2	PILE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	3.50	0.512	0.099	0.350	0.191	0.558	3.45	0.342
M2-20-P-02		0.69	0.2	PILE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	3.50	0.477	0.106	0.396	0.157	0.427	3.45	0.367
M2-20-P-03		0.69	0.2	PILE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	4.00	0.533	0.109	0.430	0.129	0.344	3.45	0.375
M2-20-P-04		0.69	0.2	PILE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	3.50	0.447	0.113	0.455	0.113	0.289	3.45	0.392
M2-20-P-05		0.69	0.2	PILE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	3.50	0.599	0.085	0.470	0.073	0.250	3.45	0.292
M2-20-P-06	M2	0.69	0.2	PILE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	3.50	0.583	0.087	0.480	0.066	0.221	3.45	0.300
M2-20-P-07		0.69	0.2	PILE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	4.50	0.692	0.094	0.482	0.065	0.200	3.45	0.325
M2-20-P-08		0.69	0.2	PILE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	3.00	0.545	0.080	0.483	0.050	0.182	3.45	0.275
M2-20-P-09		0.69	0.2	PILE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	2.50	0.500	0.072	0.479	0.042	0.168	3.45	0.250
M2-20-P-10		0.69	0.2	PILE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	2.00	0.444	0.065	0.475	0.035	0.156	3.45	0.225
M2-20-P-11		0.69	0.2	PILE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	3.50	0.751	0.068	0.469	0.034	0.146	3.45	0.233
M2-30-P-01		0.69	0.3	PILE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	6.50	0.736	0.128	0.351	0.246	0.558	2.30	0.294
M2-30-P-02		0.69	0.3	PILE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	8.50	0.927	0.133	0.400	0.194	0.424	2.30	0.306
M2-30-P-03		0.69	0.3	PILE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	7.50	0.750	0.145	0.440	0.168	0.337	2.30	0.333
M2-30-P-04		0.69	0.3	PILE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	7.00	0.676	0.150	0.475	0.143	0.277	2.30	0.345
M2-30-P-05		0.69	0.3	PILE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	8.50	0.928	0.133	0.501	0.108	0.235	2.30	0.305
M2-30-P-06	M2	0.69	0.3	PILE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	7.00	0.808	0.126	0.520	0.088	0.204	2.30	0.289
M2-30-P-07		0.69	0.3	PILE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	8.50	1.158	0.106	0.531	0.066	0.181	2.30	0.245
M2-30-P-08		0.69	0.3	PILE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	8.00	0.872	0.133	0.540	0.075	0.163	2.30	0.306
M2-30-P-09		0.69	0.3	PILE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	7.50	1.154	0.094	0.541	0.048	0.149	2.30	0.217
M2-30-P-10		0.69	0.3	PILE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	5.00	0.936	0.077	0.542	0.037	0.137	2.30	0.178
M2-30-P-11		0.69	0.3	PILE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	4.00	0.632	0.092	0.539	0.040	0.127	2.30	0.211

Part III

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**d/L_o**	**d/L***	**L (m)**	**H_i (cm)**	**H_t(cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$2\pi L/gT^2 = L/L_o$**	**H_i/L**	**B/L**	**D/d**	**H_i/d**
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M3-20-P-01		0.49	0.2	PILE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	5.00	0.731	0.140	0.350	0.191	0.558	2.45	0.342
M3-20-P-02		0.49	0.2	PILE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	4.00	0.546	0.150	0.396	0.157	0.427	2.45	0.367
M3-20-P-03		0.49	0.2	PILE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	5.00	0.667	0.153	0.430	0.129	0.344	2.45	0.375
M3-20-P-04		0.49	0.2	PILE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	4.00	0.511	0.160	0.455	0.113	0.289	2.45	0.392
M3-20-P-05		0.49	0.2	PILE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	3.50	0.599	0.119	0.470	0.073	0.250	2.45	0.292
M3-20-P-06	M3	0.49	0.2	PILE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	4.00	0.667	0.122	0.480	0.066	0.221	2.45	0.300
M3-20-P-07		0.49	0.2	PILE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	5.00	0.769	0.133	0.482	0.065	0.200	2.45	0.325
M3-20-P-08		0.49	0.2	PILE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	3.50	0.636	0.112	0.483	0.050	0.182	2.45	0.275
M3-20-P-09		0.49	0.2	PILE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	2.50	0.500	0.102	0.479	0.042	0.168	2.45	0.250
M3-20-P-10		0.49	0.2	PILE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	3.00	0.667	0.092	0.475	0.035	0.156	2.45	0.225
M3-20-P-11		0.49	0.2	PILE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	3.50	0.751	0.095	0.469	0.034	0.146	2.45	0.233
M3-30-P-01		0.49	0.3	PILE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	7.50	0.849	0.180	0.351	0.246	0.558	1.63	0.294
M3-30-P-02		0.49	0.3	PILE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	7.50	0.818	0.187	0.400	0.194	0.424	1.63	0.306
M3-30-P-03		0.49	0.3	PILE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	7.50	0.750	0.204	0.440	0.168	0.337	1.63	0.333
M3-30-P-04		0.49	0.3	PILE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	8.00	0.772	0.211	0.475	0.143	0.277	1.63	0.345
M3-30-P-05		0.49	0.3	PILE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	6.00	0.655	0.187	0.501	0.108	0.235	1.63	0.305
M3-30-P-06	M3	0.49	0.3	PILE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	6.50	0.751	0.177	0.520	0.088	0.204	1.63	0.289
M3-30-P-07		0.49	0.3	PILE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	8.00	1.090	0.150	0.531	0.066	0.181	1.63	0.245
M3-30-P-08		0.49	0.3	PILE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	7.50	0.818	0.187	0.540	0.075	0.163	1.63	0.306
M3-30-P-09		0.49	0.3	PILE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	6.00	0.923	0.133	0.541	0.048	0.149	1.63	0.217
M3-30-P-10		0.49	0.3	PILE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	5.00	0.936	0.109	0.542	0.037	0.137	1.63	0.178
M3-30-P-11		0.49	0.3	PILE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	7.00	1.106	0.129	0.539	0.040	0.127	1.63	0.211

Part IV

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**d/L_o**	**d/L***	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$2\pi L/gT^2 = L/L_o$**	**H_i/L**	**B/L**	**D/d**	**H_i/d**
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M1-20-C-01		0.60	0.2	CABLE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	6.20	0.906	0.114	0.350	0.191	0.558	3.00	0.342
M1-20-C-02		0.60	0.2	CABLE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	6.00	0.819	0.122	0.396	0.157	0.427	3.00	0.367
M1-20-C-03		0.60	0.2	CABLE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	5.40	0.720	0.125	0.430	0.129	0.344	3.00	0.375
M1-20-C-04		0.60	0.2	CABLE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	5.30	0.677	0.131	0.455	0.113	0.289	3.00	0.392
M1-20-C-05		0.60	0.2	CABLE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	4.60	0.788	0.097	0.470	0.073	0.250	3.00	0.292
M1-20-C-06	M1	0.60	0.2	CABLE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	3.20	0.533	0.100	0.480	0.066	0.221	3.00	0.300
M1-20-C-07		0.60	0.2	CABLE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	6.30	0.969	0.108	0.482	0.065	0.200	3.00	0.325
M1-20-C-08		0.60	0.2	CABLE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	5.10	0.927	0.092	0.483	0.050	0.182	3.00	0.275
M1-20-C-09		0.60	0.2	CABLE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	4.30	0.860	0.083	0.479	0.042	0.168	3.00	0.250
M1-20-C-10		0.60	0.2	CABLE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	4.10	0.911	0.075	0.475	0.035	0.156	3.00	0.225
M1-20-C-11		0.60	0.2	CABLE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	3.40	0.730	0.078	0.469	0.034	0.146	3.00	0.233
M1-30-C-01		0.60	0.3	CABLE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	8.00	0.906	0.147	0.351	0.246	0.558	2.00	0.294
M1-30-C-02		0.60	0.3	CABLE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	8.20	0.894	0.153	0.400	0.194	0.424	2.00	0.306
M1-30-C-03		0.60	0.3	CABLE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	8.30	0.830	0.167	0.440	0.168	0.337	2.00	0.333
M1-30-C-04		0.60	0.3	CABLE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	8.00	0.772	0.173	0.475	0.143	0.277	2.00	0.345
M1-30-C-05		0.60	0.3	CABLE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	7.90	0.862	0.153	0.501	0.108	0.235	2.00	0.305
M1-30-C-06	M1	0.60	0.3	CABLE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	7.30	0.843	0.144	0.520	0.088	0.204	2.00	0.289
M1-30-C-07		0.60	0.3	CABLE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	5.00	0.681	0.122	0.531	0.066	0.181	2.00	0.245
M1-30-C-08		0.60	0.3	CABLE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	5.90	0.643	0.153	0.540	0.075	0.163	2.00	0.306
M1-30-C-09		0.60	0.3	CABLE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	4.60	0.708	0.108	0.541	0.048	0.149	2.00	0.217
M1-30-C-10		0.60	0.3	CABLE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	4.30	0.805	0.089	0.542	0.037	0.137	2.00	0.178
M1-30-C-11		0.60	0.3	CABLE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	4.00	0.632	0.106	0.539	0.040	0.127	2.00	0.211

Part V

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	D (m)	d (m)	**Anchoring**	f (rpm)	T (s)	L_o (m)	d/L_o	d/L*	L (m)	H_i (cm)	H_t (cm)	$C_T = H_t/H_i$	H_i/D	$2\pi L/gT^2 = L/L_o$	H_i/L	B/L	D/d	H_i/d
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M2-20-C-01		0.69	0.2	CABLE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	7.00	1.023	0.099	0.350	0.191	0.558	3.45	0.342
M2-20-C-02		0.69	0.2	CABLE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	6.00	0.819	0.106	0.396	0.157	0.427	3.45	0.367
M2-20-C-03		0.69	0.2	CABLE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	6.00	0.800	0.109	0.430	0.129	0.344	3.45	0.375
M2-20-C-04		0.69	0.2	CABLE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	6.00	0.766	0.113	0.455	0.113	0.289	3.45	0.392
M2-20-C-05		0.69	0.2	CABLE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	5.00	0.856	0.085	0.470	0.073	0.250	3.45	0.292
M2-20-C-06	M2	0.69	0.2	CABLE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	4.00	0.667	0.087	0.480	0.066	0.221	3.45	0.300
M2-20-C-07		0.69	0.2	CABLE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	5.00	0.769	0.094	0.482	0.065	0.200	3.45	0.325
M2-20-C-08		0.69	0.2	CABLE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	3.00	0.545	0.080	0.483	0.050	0.182	3.45	0.275
M2-20-C-09		0.69	0.2	CABLE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	6.00	1.200	0.072	0.479	0.042	0.168	3.45	0.250
M2-20-C-10		0.69	0.2	CABLE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	5.00	1.111	0.065	0.475	0.035	0.156	3.45	0.225
M2-20-C-11		0.69	0.2	CABLE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	4.00	0.858	0.068	0.469	0.034	0.146	3.45	0.233
M2-30-C-01		0.69	0.3	CABLE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	9.50	1.076	0.128	0.351	0.246	0.558	2.30	0.294
M2-30-C-02		0.69	0.3	CABLE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	9.50	1.036	0.133	0.400	0.194	0.424	2.30	0.306
M2-30-C-03		0.69	0.3	CABLE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	8.00	0.800	0.145	0.440	0.168	0.337	2.30	0.333
M2-30-C-04		0.69	0.3	CABLE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	9.00	0.869	0.150	0.475	0.143	0.277	2.30	0.345
M2-30-C-05		0.69	0.3	CABLE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	8.00	0.873	0.133	0.501	0.108	0.235	2.30	0.305
M2-30-C-06	M2	0.69	0.3	CABLE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	6.00	0.693	0.126	0.520	0.088	0.204	2.30	0.289
M2-30-C-07		0.69	0.3	CABLE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	8.00	1.090	0.106	0.531	0.066	0.181	2.30	0.245
M2-30-C-08		0.69	0.3	CABLE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	7.50	0.818	0.133	0.540	0.075	0.163	2.30	0.306
M2-30-C-09		0.69	0.3	CABLE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	4.50	0.692	0.094	0.541	0.048	0.149	2.30	0.217
M2-30-C-10		0.69	0.3	CABLE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	5.50	1.030	0.077	0.542	0.037	0.137	2.30	0.178
M2-30-C-11		0.69	0.3	CABLE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	4.00	0.632	0.092	0.539	0.040	0.127	2.30	0.211

Part VI

D	Models' draft	C_T	Transmission coefficient
B	Models' width	H_i	Incident wave height
f	Frequency	H_t	Transmitted wave height
T	Wave period	**mea.**	Measured values
d	Water depth	**calc.**	Calculated values
L	Wavelength	*	Refer SPM table (Apdx. A)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Experiments	**Model Name**	**D (m)**	**d (m)**	**Anchoring**	**f (rpm)**	**T (s)**	**L_o (m)**	**d/L_o**	**d/L***	**L (m)**	**H_i (cm)**	**H_t (cm)**	**$C_T = H_t/H_i$**	**H_i/D**	**$2\pi L/gT^2 = L/L_o$**	**H_i/L**	**B/L**	**D/d**	**H_i/d**
		mea.	mea.			mea.	calc.	calc.	calc.	calc.	mea.	mea.	mea.	mea.	mea.	mea.	calc.	mea.	mea.
M3-20-C-01		0.49	0.2	CABLE	55.33	0.81	1.02	0.196	0.558	0.36	6.84	5.30	0.775	0.140	0.350	0.191	0.558	2.45	0.342
M3-20-C-02		0.49	0.2	CABLE	51.70	0.87	1.18	0.169	0.427	0.47	7.33	5.20	0.709	0.150	0.396	0.157	0.427	2.45	0.367
M3-20-C-03		0.49	0.2	CABLE	48.51	0.93	1.35	0.148	0.344	0.58	7.50	5.00	0.667	0.153	0.430	0.129	0.344	2.45	0.375
M3-20-C-04		0.49	0.2	CABLE	45.90	0.99	1.52	0.132	0.289	0.69	7.83	5.50	0.702	0.160	0.455	0.113	0.289	2.45	0.392
M3-20-C-05		0.49	0.2	CABLE	43.54	1.04	1.70	0.118	0.250	0.80	5.84	3.60	0.616	0.119	0.470	0.073	0.250	2.45	0.292
M3-20-C-06	M3	0.49	0.2	CABLE	41.50	1.10	1.88	0.106	0.221	0.90	6.00	3.00	0.500	0.122	0.480	0.066	0.221	2.45	0.300
M3-20-C-07		0.49	0.2	CABLE	39.59	1.15	2.08	0.096	0.200	1.00	6.50	4.50	0.692	0.133	0.482	0.065	0.200	2.45	0.325
M3-20-C-08		0.49	0.2	CABLE	37.91	1.21	2.28	0.088	0.182	1.10	5.50	3.50	0.636	0.112	0.483	0.050	0.182	2.45	0.275
M3-20-C-09		0.49	0.2	CABLE	36.40	1.26	2.49	0.080	0.168	1.19	5.00	4.50	0.900	0.102	0.479	0.042	0.168	2.45	0.250
M3-20-C-10		0.49	0.2	CABLE	35.03	1.31	2.70	0.074	0.156	1.28	4.50	4.00	0.889	0.092	0.475	0.035	0.156	2.45	0.225
M3-20-C-11		0.49	0.2	CABLE	33.78	1.37	2.91	0.069	0.146	1.37	4.66	3.50	0.751	0.095	0.469	0.034	0.146	2.45	0.233
M3-30-C-01		0.49	0.3	CABLE	55.33	0.81	1.02	0.293	0.836	0.36	8.83	7.50	0.849	0.180	0.351	0.246	0.558	1.63	0.294
M3-30-C-02		0.49	0.3	CABLE	51.70	0.87	1.18	0.254	0.635	0.47	9.17	7.90	0.862	0.187	0.400	0.194	0.424	1.63	0.306
M3-30-C-03		0.49	0.3	CABLE	48.51	0.93	1.35	0.222	0.505	0.59	10.00	8.00	0.800	0.204	0.440	0.168	0.337	1.63	0.333
M3-30-C-04		0.49	0.3	CABLE	45.90	0.99	1.52	0.197	0.416	0.72	10.36	7.80	0.753	0.211	0.475	0.143	0.277	1.63	0.345
M3-30-C-05		0.49	0.3	CABLE	43.54	1.04	1.70	0.176	0.352	0.85	9.16	7.60	0.830	0.187	0.501	0.108	0.235	1.63	0.305
M3-30-C-06	M3	0.49	0.3	CABLE	41.50	1.10	1.88	0.159	0.306	0.98	8.66	7.00	0.808	0.177	0.520	0.088	0.204	1.63	0.289
M3-30-C-07		0.49	0.3	CABLE	39.59	1.15	2.08	0.144	0.271	1.11	7.34	3.90	0.531	0.150	0.531	0.066	0.181	1.63	0.245
M3-30-C-08		0.49	0.3	CABLE	37.91	1.21	2.28	0.132	0.244	1.23	9.17	5.30	0.578	0.187	0.540	0.075	0.163	1.63	0.306
M3-30-C-09		0.49	0.3	CABLE	36.40	1.26	2.49	0.121	0.223	1.35	6.50	4.50	0.692	0.133	0.541	0.048	0.149	1.63	0.217
M3-30-C-10		0.49	0.3	CABLE	35.03	1.31	2.70	0.111	0.205	1.46	5.34	4.00	0.749	0.109	0.542	0.037	0.137	1.63	0.178
M3-30-C-11		0.49	0.3	CABLE	33.78	1.37	2.91	0.103	0.191	1.57	6.33	3.80	0.600	0.129	0.539	0.040	0.127	1.63	0.211